A O R T O G R A P H Y I N D I A G N O S I S

ITS APPLICATION IN UROLOGICAL AND SOME OTHER CONDITIONS

A THESIS SUBMITTED FOR THE DEGREE OF

MASTER OF SURGERY

BY

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ACKNOWLEDGEMENTS

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I am grateful to Professor W. Arthur Mackey for permission to quote the case notes of those patients with vascular disease, whom he referred to me for aortography.

I also wish to thank Dr. R. M. Thomson of the Cardiology Department for his co-operation in providing the blood pressure recordings.

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INTRODUCTION

The study of the urinary tract in the human is dependent on the various types of examination available. The direct inspection by instrumental means of the lower tract, the urographic appearances - excretory and retrograde - of the upper tract and the numerous biochemical and bacteriological investigations of the urine, both total and separate kidney specimens, have all contributed to the establishment of Urology as a very exact branch of Surgery.

These examinations, however, do not always afford a complete and accurate diagnosis. Certain gaps in the knowledge of the state of the kidneys remain; this is especially so in the case of the vascularity and therefore the actual and potential function of these organs.

Until recently, information regarding the blood supply of the kidney has been obtained from autopsy examination and animal experiments.

In the living human the demonstration of the renal vascularity is possible by translumbar aortography. This consists of the X-Ray visualisation of a radio-opaque medium introduced into the aorta by means of a needle inserted directly through the loin.

The adoption of this method of examination has been

slow and at the present time it is carried out in very few centres in Britain.

This study is based on an experience of two hundred aortic punctures performed for diagnosis in the Urological Department of the Glasgow Royal Infirmary. It is believed that this is the largest individual series in this country.

The work has extended over a period of five years but much time was spent in the early stages on improving equipment and developing technique.

The assessment of the difficulties, hazards and sequelae of the procedure is based on these two hundred examinations. The great majority - one hundred and eighty - were carried out for diagnosis of a urological condition affecting usually the upper urinary tract. The remainder were performed for intrinsic vascular lesions of the aorta, iliac or femoral arteries or to show a bone tumour.

In some patients a second puncture was performed after an interval; in addition, a number of the early radiographic results were not satisfactory. These have therefore been omitted from the discussion of the value of angiography in specific conditions. Altogether one hundred and fifty-nine patients are available for consideration.

Where operation was performed the initials of the surgeon have been included in the case reports. The urological surgery was undertaken by Mr. Arthur Jacobs (A.J.) or myself

(W.B.S.). All the operations in the section dealing with intrinsic vascular disease were performed by Professor W. Arthur Mackey. (W.A.M.)

The presentation of such a subject necessarily demands a large number of illustrations. In almost every case there is a photograph to show the arterial pattern in the particular condition. In some cases illustrations of the urograms or nephrograms have been included to demonstrate the value of angiography.

HISTORICAL.

The announcement of the discovery of X-Rays was made by Röntgen of Wurtzburg on November 8th, 1895. The significance and potential value of this new technical device, especially in the realm of diagnostic medicine, was quickly realised.

The application of X-Rays to portray relatively opaque structures of the body such as the bony skeleton was at once obvious and it is not surprising that within a few months much had been learned, not only about the normal but also about some of the pathological features of bones and joints. What does seem surprising is that within a remarkably short time attempts were made, with some success, to demonstrate the course and distribution of blood vessels.

Thus, in January, 1896, ten weeks after the discovery of X-Rays, Haschek and Lindenthal of Vienna published a photograph of the first arteriogram. This was obtained by the injection of a radio-opaque substance, in this instance an emulsion of chalk, into the main arteries of an amputated limb. In order to assess the difference between various opaque materials, a copper wire was wound round the index finger of the hand. The published photograph shows quite well the relative density of metal, bone, soft tissue and concentrated

chalk. The digital arteries are quite distinct but only the main vessels appear, none of the smaller branches from them being visible. Presumably this is due to the viscosity of the emulsion and the size of the chalk particles, the presence of thrombosis in the fine vessels, and, to some extent, the limitation of the X-Ray apparatus available. Nevertheless it is a valuable first contribution in this field of radiography.

Somewhat similar experiments and results were achieved about the same time by Destot and Berard in Lyons.

The claims of Glasgow in the pioneer work and practical advances in the new science of radiography should not be forgotten or ignored. The first announcement in this country of Professor Röntgen's discovery was received early in December 1895 by Lord Kelvin, at that time the greatest living physicist. Röntgen sent to Lord Kelvin a record of his experiments and findings, along with his original paper and some original X-Ray photographs. Lord Kelvin immediately handed these over to John McIntyre for verification and investigation of the medical possibilities.

Dr. John McIntyre, a graduate of this University, qualified M.B.,C.M., in 1885. Before embarking on his medical career he had completed his training as an electrical engineer. In addition to his appointment as consultant laryngologist to the Glasgow Royal Infirmary, Dr. McIntyre

was also consultant medical electrician and had already made available, for the first time, electricity for use in the wards and operating theatres of a hospital. He at once corresponded with Röntgen and received from him one of the original tubes. He then founded in the Glasgow Royal Infirmary what is now recognised to be the second oldest diagnostic X-Ray department in the world. He applied his extensive knowledge and enthusiasm to the new science and was the first to demonstrate by X-Rays, a stone in the kidney as well as soft tissue structures such as the heart. He also entered at an early date, the field of arteriography and carried out numerous experiments on blood vessels.

The early pictures of arteries were, however, all obtained by injecting the vessels of amputated limbs or parts removed at autopsy. The solutions and emulsions tried in the early days consisted of chalk, used by Haschek and Lindenthal, calcium sulphate used by McIntyre and eventually various compounds of bismuth and barium. None of these compounds, however, proved suitable for injection into the living patient by reason of their toxicity, insolubility or difficulty of elimination.. In addition to this the early X-Ray equipment required a prolonged exposure. At the beginning of the century for example, the exposure time required to demonstrate a stone in the bladder was in the region of two hours! Apart then from the local and systemic effects of these noxious

injection media, the rapid dissemination of them throughout the circulation quite obviated the fulfillment of arteriography in the living subject and twenty-five years were to pass before that achievement.

In 1923, Sicard and Forestier of France, having discovered the radiological value of Iodised poppy-seed oil when injected into dogs, decided to apply its use to the human. After slowly injecting 4 ml. Lipiodol into the antecubital vein of a man, they saw with the fluoroscope the flow of this drug through the right side of the heart into the pulmonary arteries and out to the capillaries.

Some months later, in December of that year, Berberich and Hirsch of Germany obtained the first angiograms of peripheral vessels in the living patient. The solution used was one of the Halogen compounds - Strontium Bromide - which they injected into the arteries and veins of the arm and hand.

The following year saw a great advance in the technique and practical application of peripheral arteriography. Brooks of U.S.A. in March, 1924, published an account of the first successful living arteriogram of the leg. By this time considerable technical advances had been made in connection with the various X-Ray factors and the main problem remaining was that of a suitable radio-opaque medium.

Brooks used a solution of Sodium Iodide in the

strength of 100 gm. to 100 ml. water. This gave a good definition and at the same time, whilst not non-toxic, was at least tolerable. The risk of acute iodism, although a very real one, was to a great extent accepted and offset by the possibility of arteriography of practical value in peripheral vascular disease.

The technique described and followed by Brooks is interesting and applies to the examination of the arteries of the lower limb. Under local anaesthesia the femoral artery was exposed at the proximal end of Hunter's canal and a Crile's clamp placed in position. A needle was inserted into the artery below the clamp which was then closed. The patient was anaesthetised with Nitrous Oxide before the injection of Sodium Iodide. The clamp was released and photographs taken to demonstrate the flow of dye. Brooks found the use of general anaesthesia essential before the injection of the medium as the intense pain and spasmodic movement caused by the Iodide could not otherwise be controlled. The quality of the pictures obtained by this method was very good and it remained for many years with perhaps minor modifications the standard practice for peripheral arteriography.

Thus we have seen how, after a period of twenty-five years, there developed from primitive pictures of cadavers a reasonably good technique of arteriography of the limbs of living subjects. There remained the problem of outlining the

deep-seated vessels of the body.

It is to Reynaldo dos Santos of Portugal that credit must be given for the first successful arteriograms of the abdominal vessels by translumbar aortic injection. Dos Santos and his associates, Lamas and Caldas, started their work in 1925 and published their results in March, 1929.

The following brief description of the procedure by which this new radiological field was opened up is not out of place in this historical section.

The technique of puncture originally described remains the basis from which all subsequent techniques have evolved.

The needles used were 14 cm. long with an external diameter of 1.2. mm. The needle was introduced on the left side 8 cm. from the midline and directed medially and upwards until it entered the aorta.

The level at which the needle punctured the aorta depended on which of the branches were to be outlined. Thus to show the coeliac axis, puncture was made at the 12th thoracic vertebra; for the renal arteries, at the 1st lumbar vertebra and for the inferior mesenteric artery, at the 2nd lumbar body. In order to demonstrate the first branches, puncture had to be made at the 10th thoracic, but the possibility of inflicting damage on the lung was not considered serious by dos Santos.

The medium used was Sodium Iodide in high concentration, 80-100% and usually some 20 ml. was introduced under pressure by means of a compressed air machine.

Following the presentation of his paper and his report to the French Academy of Science and later to the American Medical Association, much controversy arose regarding the value and dangers of aortography.

Despite the report by dos Santos that 300 aortic punctures had been carried out for diagnostic purposes with no mortality or appreciable morbidity the reception to this new idea was cool. In this country his paper to the International Urological Society Congress in June, 1933, held in London was ignored.

There was an understandable natural antipathy to the blind puncture of the main artery of the body. There was the fear of the immediate risk of haemorrhage and the suspicion that sequelae such as aneurysm or embolism might develop later. In addition there remained the indisputable objection to the toxic effect on the blood vessels and abdominal organs of Sodium Iodide or any other compound available at that time. The general opinion was that the diagnostic value of aortography was doubtful and at best very limited. With few exceptions the procedure was regarded as unjustifiably hazardous in the human.

In 1931, Legueu, Fey and Truchot of France recorded

their experiences of translumbar aortography in 20 cases. Four serious reactions were reported. There was one case each of acute iodism, nephritis, haematuric nephritis and hyperazotaemic oedema.

In 1932, Balestra of Italy recorded his experiences of a few cases in which aortography was done for aneurysm of the abdominal aorta and arteriosclerosis. No urological cases were examined.

In 1933, Osario of Spain reported 100 cases with no ill effect. The medium used consisted of 30 cc. Methiodal 90%.

In view of the somewhat conflicting reports about the dangers of the procedure, Henline and Moore of U.S.A. in 1936 undertook the trial of aortography on animals before extending it to man.

These experiments were conducted on dogs, who following aortic puncture, were injected with Sodium Iodide 100%. The results were as follows:-

Two of the dogs were deliberately sacrificed so that they cannot be included in the total mortality figures.

The first animal was submitted to observation of the kidneys which immediately following the injection "went blue but recovered". The second dog was sacrificed at 36 days and examination of the aorta showed that complete healing had occurred. The fate of the remaining 19 dogs was interesting. In five cases death was attributed directly to haemorrhage

from the aorta. Three dogs showed strong evidence of toxicity consisting of haemorrhagic nephritis, effusion of fluid into the pericardium and peritoneal cavity with congestion of the liver.

Histological examination showed in a number of cases (not stated) separation of the layers of the aorta.

The remaining eleven dogs recovered and lived.

The results of this animal experiment in which from trauma or toxicity there was an immediate mortality of nearly 50% had a profound effect on the employment of aortography in the human.

In addition, these authors quote Balestra as saying that dos Santos had seven deaths following aortic puncture. This serious statement which has been quoted on more than one occasion against the use of aortography is a complete mistranslation of the article. The correct translation and interpretation which I have had confirmed, leaves no doubt that Balestra, in discussing the relative security of aortic puncture, correctly quoted dos Santos as follows:-

Seven deaths occurred from various causes and at different times after aortography. All of these were submitted to accurate post-mortem examination. In five of the cases death occurred on the 20th, 16th, 14th, 6th and 5th days after puncture. In three of these patients marked

atheroma was present in the aorta but in none of the five patients could any evidence be seen of the aortic puncture. The sixth, a patient with iliac thrombosis, died 24 hours after aortography. In this case some evidence of bleeding was seen in the muscles along the track of the needle, but not from the aorta. The seventh patient died from haemorrhage after hysterectomy, due to a slipped ligature and showed some ecchymosis around the aorta but this was not the cause of death.

At this stage some critical comment may be made on these adverse results obtained in animal experiments by Henline and Moore.

In the first place, the size and weight of the dogs used is not given, but it is reasonable to assume that on the average they did not exceed 20% of that of the average adult human. This is of importance when comparing the effect of the size of the needle as a traumatic factor and the dose of the medium as a toxic factor.

The aorta of any dog is much smaller not only in calibre but also in the thickness of the vessel wall. In addition the relative size and composition of the coats of the aorta differ between dog and man. One very important factor as regards the effect of puncture is that the elastic tissue of the media which is responsible for the sealing effect is relatively much less in the dog. The needles

used varied from 18 S.W.G. to 22 S.W.G. As the needle used by dos Santos was equivalent to 18 S.W.G. there is a great difference in the degree of injury inflicted by it on dogs compared with the human.

The quantity of Sodium Iodide injected, varied between 10-20 ml. As this is the usual dose given to a human, the amount per kg./body weight is at least five times greater in dogs than in man and the systemic toxic effect must be greater. The local effect of Sodium Iodide on the arteries of dogs was studied by Paolucci in 1931. He found that 100% Sodium Iodide caused destruction of the intima and in some cases necrosis of the media and adventitia. In addition chemical changes were noted in muscle fibre and in a number of cases thrombosis of the smaller vessels occurred.

Such marked changes have not been reported as occurring, with the same frequency, in peripheral arteriography in the human and there is no reason to suppose that the effect on the abdominal vessels would be any more marked.

Thus we have proof that in respect of aortic puncture and injection of iodide, the anatomy and physiology of the dog is not exactly comparable to that of the human. Further proof of this difference is seen practically by the number of aortograms which have now been reported without mortality.

The adverse results of the animal experiments of

Henline and Moore did nothing to allay the fears of the danger of aortic injection in man. There was indeed considerable scepticism about the good results claimed by dos Santos and suspicion was more than once raised in America that his assertions about the hazards were too sanguine. Dos Santos has on many occasions stated that he has had no death directly attributable to aortography and has reaffirmed this in a personal communication to me.

The almost awesome respect for the sanctity of the aorta continued for several years until 1941, when Farinas in the U.S.A. in an effort to overcome needle puncture of that artery, produced aortograms by the retrograde passage of a catheter inserted into the femoral artery. The following year, however, Nelson (1942) and Doss (1942) of America, working independently, each published a short series of cases in which the translumbar method, as advocated by dos Santos, was used. Later, in 1946, Wagner reported three further cases. These three American surgeons were enthusiastic about the procedure and the results they obtained and have continued to publish favourable reports. It is largely due to them and of course to dos Santos that translumbar aortography was not permitted to fall into disuse and has now become accepted as a justifiable and valuable aid to diagnosis.

Above all, tribute must be paid to dos Santos, not only for his originality but also for his courage and vision

in the face of considerable opposition.

The first British record was that published in December, 1950, by Griffiths, who reported a series of 25 cases carried out mainly for renal diagnosis. Since then various publications, including the writer's (Stirling, 1953, 1955, a.b.c.) have appeared, describing its value in urological and vascular disease.

My interest was aroused some ten years ago, but like others I did not feel justified in adopting it until after Griffith's publication in this country, when I had an opportunity of discussing the procedure with him.

CONTRAST MEDIA.

The story of the development of contrast media used in urological diagnosis is both interesting and pertinent.

Following the incorporation of the Edison lamp into the Nitze-Leiter cystoscope in 1880, the examination of the bladder was made safe, easy and efficient. The increasing knowledge gained only served to stimulate the search for methods which would give information about the upper urinary tract.

The introduction of X-Rays enabled the bladder to be

visualised by means of radio-opaque solution instilled into it. This in itself, however, was of little value because of the unsatisfactory medium and the fact that cystoscopy was much more revealing.

An attempt was made by Klose in 1904 to outline the ureter and renal pelvis by the injection up from the bladder. The solution used was a Bismuth one but failed because it was too viscid. Later, in 1906, Voelcker and Lichtenberg, when carrying out cystoscopy with Collargol, found that the fluid had regurgitated up the ureter and outlined both ureter and renal pelvis. Little attention, however, was paid to this until about 1910, when the value of instrumental pyelography was recognised and from then on to the present day its use has become universal.

A large variety of solutions has at one time or another been tried, most of which have been discarded. Colloidal silver was the first to be used and continued in favour for some years. Silver oxide, Nargol and other silver salts were tried out and silver iodide became popular. Eventually Sodium Bromide and Sodium Iodide became established the latter being deservedly more popular and it is still used today.

Meanwhile, Urologists had long hoped that some solution might be found which would be excreted by the kidney and give a shadow on radiography. Indeed at the time of the

introduction of instrumental pyelography, Voelcker and Lichtenberg attempted excretion urography using the colloidal heavy metals but had to abandon it because of the great toxicity of these preparations. In 1923 Rowantree and Schole took up the problem and by administering Sodium Iodide either intravenously or by mouth were successful in visualising the upper urinary tract in about one-half of their cases. In 1927, Rosenb achieved a passing success with Pyelognost - a compound of Iodine and urea, but this was not eliminated rapidly enough and produced iodism.

The discovery of the modern organic iodide compounds was, like many other advances in medicine, somewhat fortuitous.

Binz, while working with the Benzine ring in an attempt to improve the Salvarsan group for use in syphilis, found that when iodine was attached to the pyridine nucleus it became a valuable antiseptic in the treatment of mastitis in cows. This drug was called Selectan and was known to be excreted in the bile and in the urine. On administering an allied compound to human beings a picture of the urinary tract was obtained.

After much research a compound, Uroselectan, was found (1929) which whilst very satisfactory was cumbersome to prepare and use. Persistent research by Lichtenberg and his colleagues resulted in 1931 in the production of Uroselectan-B. This is the original compound of the group of drugs now known

as Iodoxyl.

Almost immediately after the introduction of Uroselectan, another excretory substance was brought forward under the name Abrodil. In 1932 it was superseded by a more efficient but somewhat similar compound named Perabrodil - (Neoskiodan in America.) and this is the original of the group known as the Diodone drugs.

Up to 1939 these two drugs mentioned were the only ones available and were imported into this country from the Continent. Since then Iodoxyl and Diodone in various strengths have become available under numerous proprietory designations.

In 1950 a new organic compound, Sodium Acetrizoate was introduced. This is a Tri-molecule organic iodide compound and has a higher iodine content than any other Iodoxyl or Diodone preparation. In addition it is less toxic and more rapidly eliminated than anything so far available.

The development of these contrast media for excretion urography, with their lessening toxicity, led to their use in Radiodiagnosis elsewhere. As they are less irritating than Sodium Iodide the only limiting factor to their general use in ascending pyelography is the cost. Cost alone, however, was not the only contra-indication for their immediate adoption for arteriography.

The iodine content of the older Iodoxyl and Diodone

drugs was in the nature of 40% whilst that of Sodium Iodide is 85%. The density of the shadows was so inferior to that of Sodium Iodide that until the stronger solutions of 70% were introduced Sodium Iodide remained the drug of choice.

The property of the Iodide compounds of being excreted rapidly in the urine is of no account in peripheral arteriography: any solution of comparable density or toxicity would be equally efficacious. The great advantage of using the Iodides in aortic injection for renal arteriography is due to their elimination by the kidneys, the entire process being visible by radiography.

EARLY AND ORIGINAL WORK.

AUTOPSY FINDINGS.

Accuracy of aortic puncture demands a knowledge of regional anatomy. Whilst this region was familiar through the surgical approach to the kidney it was thought advisable to gain further knowledge and familiarity in the use of needle puncture by preliminary practice. Accordingly, before performing aortography on a patient, some forty punctures were carried out in the post-mortem room.

After each puncture a careful dissection of the needle track was carried out. The angle of the track, the depth at which the various structures were encountered and finally the location of the needle point were all carefully noted.

One difficulty encountered was in knowing when the needle point lay in the centre of the aortic lumen. Although the sensation of overcoming the resistance of the aortic wall is usually felt there is no confirmatory evidence, as in the living patient, of a stream of blood from the needle. After the first few attempts, however, it was possible to place the needle adequately in about 75% of cases.

The experience and practice so gained proved valuable later when the procedure was used on patients.

Details of the technique of puncture in the living subject will be given later in the appropriate section, but a brief description and illustration of the anatomical course of the needle is included here.

The needle is inserted not more than 1 cm. below the twelfth rib on the left side 8 cm. from the midline. It is directed upwards, medially and forwards in the direction of the first lumbar vertebra (or twelfth thoracic.)

The accompanying diagrams on the following page illustrate the course of the needle. Diagram 1, is that of the transverse plane at the level of the first lumbar vertebra. The needle track, however, is oblique as shown in diagrams 2 and 3 and extends from the skin puncture at the level of the second or third lumbar vertebra (depending on the obliquity of the twelfth rib) upwards to the first lumbar or twelfth thoracic bodies.

In its course to the aorta the needle is directed against the vertebral body (needle 1, diagram 1) at which stage the fibres of the left crus of the diaphragm are encountered. The needle is withdrawn to clear these muscle fibres and then advanced so that it passes round the edge of the vertebral body and enters the aorta. (Needle 2, diagram 1)

Throughout the whole procedure the following structures are traversed; skin, fascia, sacrospinalis muscle bundle, quadratus lumborum, lumbodorsal fascia, psoas muscle

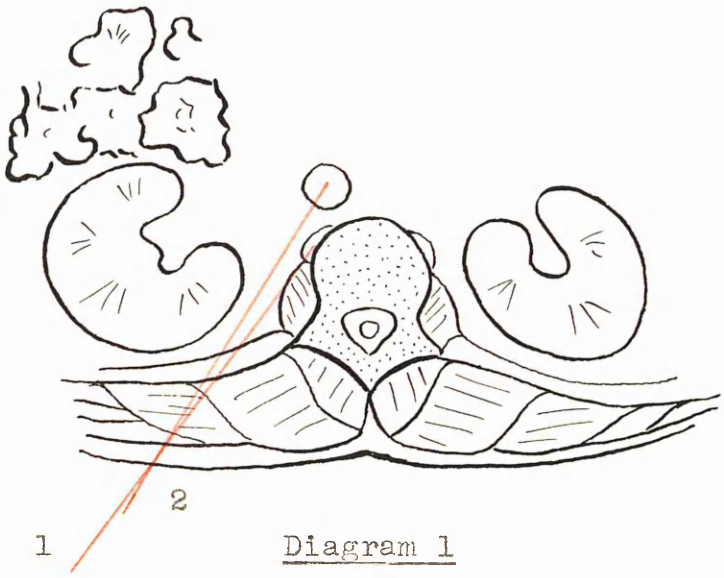


Diagram 1

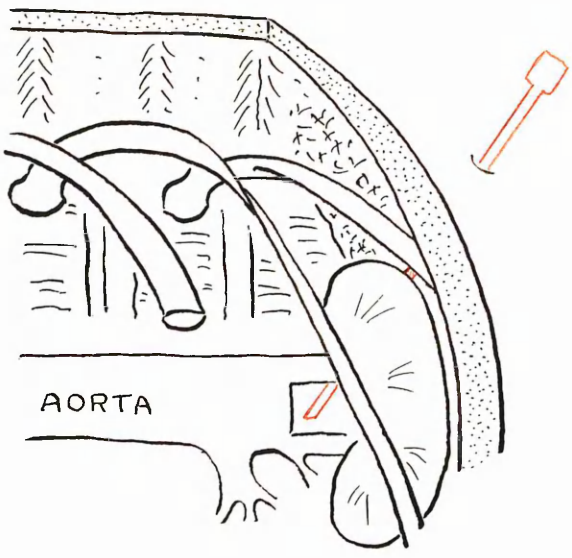


Diagram 2

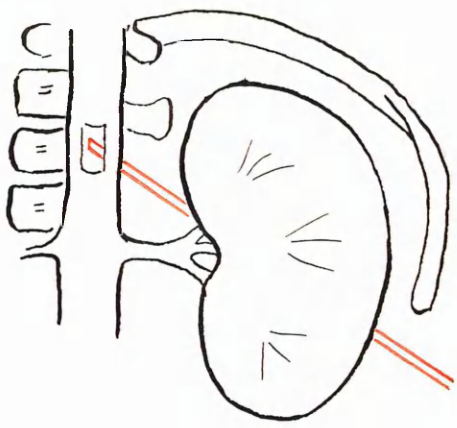


Diagram 3

occasionally and left crus of diaphragm.

Reference to the diagrams shows that at no point in its course should the needle penetrate any solid or hollow viscus other than aorta. This is still the case even where there is considerable variation in the size and build of the patient and with a fixed skin puncture site 8 cm. from the midline.

In addition to the regional dissections carried out the opportunity was taken of examining in detail the area of aorta into which puncture might be made. The standard text books of Anatomy did not afford sufficient accurate information regarding the size and relationship of the aorta and its main branches.

Experience, both in the post-mortem room and subsequently in the measurement of the aorta following aortography, shows that the size of that vessel is directly proportional to the build and weight of the patient. This is true except in some cases of advanced arteriosclerosis.

The internal diameter of the aorta just above the renal arteries was found to vary on post-mortem examination between 1.5 cm. and 2.1 cm. This, however is not a true indication of the actual size during life when the vessel is filled with blood at a normal or raised blood pressure. In

the average case the increase in diameter during life is in the region of 0.5 cm. as judged on the aortogram.

The detailed examination of the renal arteries raised several interesting points, some of which had not previously been appreciated.

The level of origin of these arteries is quite variable. In this respect the X-Ray visualisation is more reliable then the post-mortem dissection.

Analysis of 100 aortograms in which the kidneys were normal as regards position and none of which had a congenital anomaly, shows a wide variation in the level of origin of the renal arteries.

The following table shows the actual levels of origin of the right and left renal arteries.

The usual anatomical description states that these vessels arise 1.5 cm. below the transpyloric plane at the level of the first lumbar vertebra. This, whilst adequate for general purposes is not accurate enough for exact aortic puncture.

It is seen that in some 50% of otherwise normal kidneys the arteries arise between the lower border of the first lumbar and the upper border of the second lumbar vertebrae. The remainder usually arise between the limits of these two vertebral bodies, a distance of at least 6 cm. When the extreme limits between the twelfth thoracic and third

lumbar vertebrae are taken into account and also the common occurrence of accessory vessels at different levels, the variation is even greater.

Where congenital renal anomalies exist, the renal blood supply may arise almost anywhere between the diaphragm and the bony pelvis.

RENAL ARTERY ORIGIN.

LEVEL		RIGHT		LEFT	
T.12		2%		0	
L.1	upper	14%		8%	
	middle	16%	54%	16%	50%
	lower	24%		26%	
L.II	upper	30%		30%	
	middle	7%	41%	12%	49%
	lower	4%		7%	
L.III	upper	1%		0	
	middle	1%	3%	1%	1%
	lower	1%		0	

The distance between the origins of the superior mesenteric artery and the renal arteries is likewise very variable. Whilst on the average it appeared to be about 1cm. frequently it was found to be much less. On more than one occasion the three vessels were seen to arise from the aorta at the same level.

This variation, both in the level of origin of the aortic branches and their relationship to each other is important. Absolute accuracy in positioning the needle at the supposed site of election for renal angiography, between the superior mesenteric and renal arteries, cannot be achieved in every case.

Such accuracy, however, is not essential, as was previously thought and further reference to this will be made when the technique which I use is described.

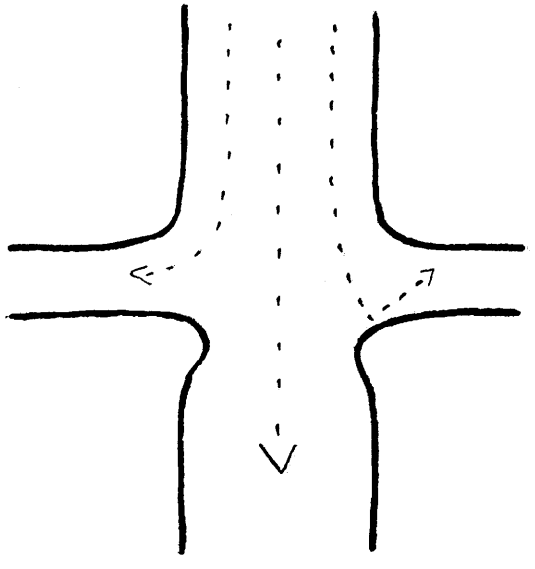
The renal arteries arise almost at right angles from the aorta at slightly different levels - the right usually lower than the left. They do so in a particular fashion.

The lumen of each artery at its opening into the aorta is considerably larger than it is some 3-5 mm. distal to its origin.

The lower lip of the opening projects very slightly into the aorta so that some diversion occurs and is continued by the constant stream of blood. This

configuration applies only to the major vascular beds of the abdomen supplied by the coeliac axis, mesenteric and renal arteries.

The diagram below, which is exaggerated, illustrates this sequence.



CLINICAL AND EXPERIMENTAL FINDINGS.

The technique first employed was in the main that published by Griffiths. A brief description of this is now given and a commentary of the results which I obtained by this method.

The apparatus consisted of a No. 18 S.W.G. needle which was attached to the distal end of a length of rubber pressure tubing. Into this a glass inspection tube was incorporated. To the proximal end of this tube there was attached a three-way adaptor from the side arm of which was a short length of tubing.

The whole system was filled with saline from a syringe attached to the side arm tubing.

The patient, who had been anaesthetised, was placed prone on a non-opaque wooden tunnel on which was a stationary grid. This tunnel accommodated three cassettes and by means of wooden handles these films could be moved rapidly across the area enabling photographs to be taken every 2-3 seconds.

The needle with the saline-filled system attached was introduced into the aorta and perfusion of saline continued by an assistant.

When blood was seen to come freely into the glass tube on suction, saline perfusion was stopped and a syringe

containing 30 ml. dye was connected to the adaptor and rapid injection made. The first film was exposed when 15 ml. had been injected and subsequent films taken as described through the tunnel at intervals of two to three seconds.

In spite of the apparent simplicity of this method the results obtained were not considered satisfactory. Whilst a number of the pictures were adequate for diagnosis, neither the definition nor the quality of the films was good and in some instances no information at all was gained. In addition to this many technical problems were encountered and the following account describes the efforts made over a period of eighteen months to overcome the various difficulties.

FITTINGS.

The original fittings and mounts between needle, tubing and syringe were of the standard "Record" type. In practice it was found that such a fitting was neither air nor water tight when pressure was applied. On more than one occasion separation of the component parts occurred. This meant that either an insufficient quantity or no dye at all was introduced into the aorta. In an attempt to overcome this a bayonet type of fitting was tried out but it did not prove entirely reliable. Eventually the screw Luer-Lok type was found to be quite satisfactory. This fitting is air tight, water tight and completely secure. The only disadvantage is

one of weight. This is of no importance except when a rather heavy three-way Luer-Lok adaptor is connected to the needle but such is not necessary with the technique now used.

SYRINGE.

In order to inject a quantity of dye such as 20 ml. through a needle of 18 S.W.G. bore in the quickest possible time, various types and sizes of syringe were tried out. All-glass, all-metal and metal and glass types of 20, 30 and 50 ml. capacity were used to determine which would permit the fastest delivery. The larger types whilst suffering on the grounds of increased pressure being required for their larger surface area had the merits of being easier to grasp and also apparent added strength. Various modifications in the form of three-ring finger grips or a flat metal top to the end of the plunger were tried out. Pressure, by a wooden batten or against the operator's chest did not prove very effective.

None of these measures succeeded in delivering the dye at a faster rate than 6 seconds for 20 ml. through a No. 18 S.W.G. needle and 3-4 seconds for a No. 16 S.W.G. needle.

Consideration of the pieces of equipment showed that there were too many variations in the calibre of the system. Thus, there was the bore of the needle, the connection to the tubing, the glass connection, more tubing, the three-way adaptor with a small bore and finally the syringe. The sum

of these different calibres gives rise to considerable resistance.

Finally, one other point of practical importance emerged. On one occasion whilst forcible pressure was being performed manually, the syringe broke and shattered in the hand. This unfortunate accident convinced me that some safer and more efficient method must be devised.

TUBING

The pressure tubing used, to begin with, was of the ordinary rubber type. In spite of its apparent strength it was found in practice that after it had been autoclaved and used several times, it was not strong enough to stand the pressure even of hand injection. Thus "ballooning" of the tubing might occur and so defeat any effort of maintaining an even, concentrated pressure. In fact this occurred on several occasions in the early cases.

Various types of plastic tubing material were tried but were found difficult to fasten securely to the metal connections. This was particularly the case when forcible mechanical pressure was instituted.

The most satisfactory type consists of rubber pressure tubing which has an additional cotton woven sheath. This has proved to be quite secure and in no case has any expansion occurred even with the technique used of forcible

injection.

INJECTOR

Once the difficulties of the mounts had been overcome by the adoption of Luer-Lok fittings and the special pressure tubing had been acquired, there remained the problem of more rapid introduction of the dye.

No improvement seemed possible with hand pressure and some mechanical device was required. There were already in existence two such instruments for rapid injection.

The first of these was that described by dos Santos (1931) and subsequently used by Doss (1944) and Nelson (1945). It consisted in the use of a cylinder of compressed air or oxygen. It was felt that there were two serious defects in such an instrument. In the first place there was a risk of the accidental introduction of air into the aorta. In spite of assurances regarding the mechanical integrity of such an apparatus, the development of some small defect or a human error in manipulation might permit a major tragedy.

The second objection lay in the lack of control over the injection and the absence of sensation of touch by the operator.

The second type of injector consisted of a strong spring action as described by Melick and Vitt (1948). The objections to this type lie in a certain limitation of pressure

and again the lack of control.

The solution appeared to lie in some form of pressure applied by leverage under manual control which would fulfil the necessary criteria. These may be defined as adequate pressure, complete control and tactile perception.

Accordingly I had constructed for me in the hospital such an instrument. The practical results achieved by it fulfilled my expectations.

The success of this instrument led to its adoption by the instrument makers who carried out certain modifications and improvements.

The illustration on the following page is reproduced by courtesy of "The Lancet".

The apparatus is all-metal with a heavy base to provide stability. The angled supports at one end are transfixed by a spindle on which the lever is hinged. The spring keeps the lever in the "up" position and also provides some tension. The vertical rods nearer the centre are threaded and support the platform on which rest the shoulders of the syringe. The clips which keep the syringe in the true vertical position are hinged and tightened by a butterfly screw. The upper clip is applied to the rim of the barrel, the lower one steadying the syringe. In this way compression of the barrel is avoided which in the case of an all-glass syringe results in increased resistance. This fact may be easily

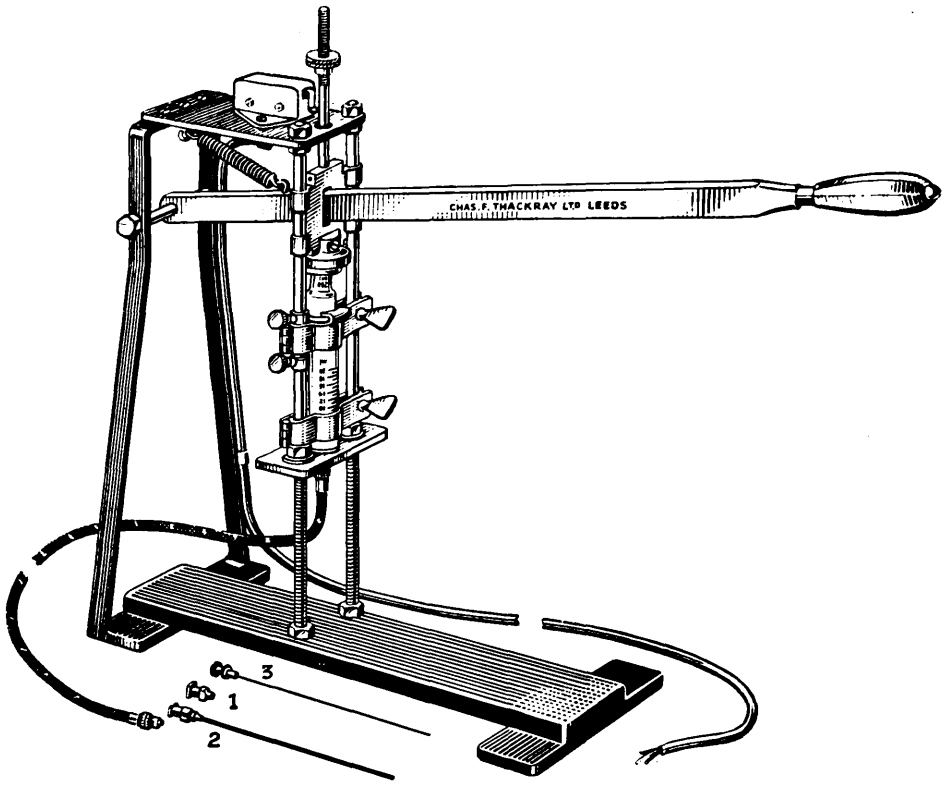


Fig. I—The injector.

proved by grasping an all-glass syringe in the hand.

The platform is adjustable on the threaded rods and the clips are interchangeable so that different sizes of syringe may be used - e.g. a 50 ml. syringe for angiocardiography.

The lever passes through a slot in the vertical metal plate which slides on the rods, the cup-shaped attachment on the lower side depressing the plunger of the syringe. To

prevent the plunger being depressed too far an adjustable metal ring is threaded on the rod extending upwards from the plate. This ensures the introduction of a measured quantity of medium. A simple electrical contact switch connected to the X-Ray machine is fixed on the top platform and activated by the screw "stopper".

Proof of the practical value of the instrument is afforded by the results of more than one hundred and fifty occasions on which it has been used.

In no case has the slightest damage, not even a tiny crack, occurred in any of the all-glass syringes.

The fluid can be injected at a rate far in excess of that by any other method. It is possible to inject 20 ml. in 0.5 sec. The efficiency of the instrument in this respect is not surprising as the mechanical advantage of vertical lever action is immense. Indeed to begin with, some anxiety arose as to whether it was not too powerful. This, however, is a matter entirely under the control of the operator. At the same time tactile perception can still be appreciated.

The radiological results confirmed the theory that the more rapid the injection the greater the concentration of dye and the greater the concentration the better the definition and extent of the arteriogram. The arteriograms so produced are, in my opinion, far superior to those obtained by manual injection.

X-RAY FACTORS.

The problem of fast injection having been solved attention was turned to the radiological factors which might influence the production of good films.

Even where good co-operation exists between the operator and the radiographer, there is an inevitable lag between the word of command to take the picture and the actual pressure on the exposure switch. Whilst such a delay may be very slight and of no moment in the subsequent films, it is of vital importance in the first film which shows the arteriogram. This is particularly so in the case of renal angiography. If co-operation is not good through inexperience on the part of the radiographer, or for any other reason, it is unlikely that any arteriogram will be obtained.

In order to eliminate such delay in the split-second timing necessary, the electrical contact switch already described was fitted to the injector. By adjustment of this switch it is possible for the operator to obtain an immediate exposure when a known quantity of dye has been delivered at a known speed. This has contributed to the production of good films.

The use of the wooden tunnel and fixed grid advocated by Griffiths was shortly abandoned as the quality of films so obtained was thought to be rather poor. A return was made to the usual X-Ray technique using a Potter-Buckey

diaphragm. In order to speed up the number of films taken a machine was modified so that the cassettes could be pushed right through instead of being removed and a fresh cassette placed on the tray. This is not considered necessary in urological diagnosis.

Various types of "seriographs" to permit a number of films to be taken quickly have been described recently. One serious disadvantage which most of them have in use is the degree of movement which goes on during the mechanical action of changing cassettes. The quality of the picture produced is not impressive. In my opinion, the solution to problems of visualisation of blood flow in the kidney lies in the development of cine-radiography or fast photography. Until something like six films per second of high quality are available, I prefer to continue with the present technique.

The radiological factors will depend on the type of machine available but elaborate equipment is not essential.

The exposure factors used in this series, carried out in the Urological Department of the Glasgow Royal Infirmary, were, for the average adult as follows:-

72 kV, 200 mA, 4.2 amps., 0.2 sec., 1/3 sec. Buckey, at an anode-film distance of 40 inches.

Where more efficient equipment is available an exposure of 0.1 sec. and 300-400 mA will give finer films.

EXPERIMENTS CONCERNING VARIOUS FACTORS IN AORTIC INJECTION.

EFFECT OF VELOCITY.

The injection of 20 ml. of fluid through a needle with an internal diameter of 1 mm. in one second produces a muzzle velocity of 2,000 cm./sec. This is twenty times the accepted normal velocity of the blood stream in a large artery.

The effect of the projection of such a thin, concentrated jet of fluid with a high velocity on the delicate lining cells of the internal coat of the aorta was unknown. It was thought possible that in spite of the rapid fall in velocity which occurs from the muzzle onwards a disruptive lesion might be produced affecting the intima and even the media of the aorta.

In order to determine the effect, if any, the following experiments were carried out.

The aorta was removed at post-mortem shortly after death, in several subjects who had no appreciable vascular disease.

(a) In the first experiment, a length of aorta from the coeliac axis trunk above to the inferior mesenteric artery below was carefully emptied of blood and clot. It was left

intact in its normal tubular form.

A No. 16 S.W.G. needle was inserted into the left postero-lateral aspect just above the renal artery as in aortography. The point of the needle was placed exactly in the centre of the lumen of the aorta, in this instance being 0.8 cm. from the vessel wall. Rapid injection of 20 ml. water was made and after opening the aorta the target area, measuring 1.5 cm. x 1.5 cm. was removed. This was submitted to serial section and histological examination made. In this case, owing to the size of the tissue, 150 sections were cut in the horizontal plane and a large area examined. No evidence was found of any damage to the intimal cells, nor was there any elevation of this layer from the underlying media.

The absence of any disruptive effect in this experiment was thought to be significant for the following reasons.

The injection was made across the lumen of an empty aorta and therefore across air.

When injection is made in the living patient, the reduction of velocity must be considerable because of the high resistance offered by a heavy fluid such as blood, compared with air. Further the column of blood is not static but has a velocity itself of 100 cm./sec. This, acting at right angles to the projected stream, would have a considerable effect on deflecting the stream and reducing its force.

The reduction is further minimised by the injection being made not at right angles, but at an angle of 45° against the aortic stream.

The reassuring result of the first experiment required confirmation and a slightly different technique was used.

(b) Two aortas were obtained, fresh from the post-mortem room, opened up and carefully cleaned of blood and clot by gentle immersion in Darrow's solution. A square of aortic wall was pinned out flat on cork and forcible injection made across air at right angles to the target. In the first case the point of the needle was placed at a distance of 0.5 cm. vertically over the centre of the aortic field and in the second at a distance of 1.0 cm. Under direct vision, the point of impingement to the centre of the field was carefully noted. The tissue was trimmed to a small area through which vertical serial sections were cut.

(c) A similar procedure was adopted for two squares of aorta, but in this case each was pinned out under Darrow's solution. The needle point was adjusted to a distance of 0.5 cm. and 0.75 cm. and injection made through the Darrow's solution.

Histological examination of 400 serial sections of the four pieces of aorta cut in the vertical plane showed no evidence of disruptive effect, either in the form of intimal cell damage, or elevation of the intima from the media.

The results of these experiments suggest that the high velocity of the jet produced by rapid injection may be discounted as a source of danger when pressure aortography is performed on the living patient.

EFFECT ON INTRA-AORTIC PRESSURE.

The results of experiments on animals and man show that there is some slight difference in the intra-arterial pressure in different large vessels of the body. Thus, in animal experiments, it has been demonstrated that there is a slight fall in the pressure along the length of the aorta and it is reasonable to expect the same in man. This fall is almost certainly due to loss of volume occurring in the large branches - a loss which is not completely compensated by intrinsic vascular tone or peripheral resistance.

The acceptance of such a slight progressive fall is reasonable and of little practical importance. Nevertheless,

I was unable to find any record of the aortic blood pressure in man at or about the level of the renal arteries having been confirmed by practical experiment. Such an experiment is simple when aortic puncture is carried out for diagnostic purposes. One consideration, however, is that the record of the blood pressure so obtained was that of a patient under general anaesthesia and therefore not a true record of the normal blood pressure reading of that patient. Nevertheless it was thought to be of interest to record several such pressures and to compare the results against those obtained simultaneously from the brachial artery by the usual cuff sphygmomanometer method.

Two other important investigations arose out of the estimation of blood pressure in the aorta and the forcible injection of fluid into it.

First, is there an appreciable rise in the intra-aortic pressure over any length of the aorta?

Second, if there is any rise in the intra-aortic pressure is that transmitted in any degree to the renal arteries?

The lever apparatus used to obtain the injection of 20 ml. of fluid in 1 sec. produced, at the time of the original experiment, an unknown pressure.

The most accurate method of measuring the pressure of the blood stream is by the electro-manometer. If the rise in pressure in the aorta was considerable there was a risk

that damage to the machine might occur or a technical fault develop and harm the patient by the introduction of non-sterile fluid into the blood stream.

Whilst it did not seem likely that the introduction of 20 ml. of fluid into the aorta even at great pressure and very rapidly could raise the intra-arterial pressure significantly, it was thought advisable to carry out initial experiments using a simple water-type manometer.

Experiment I.

A standard blood transfusion bottle containing 500 ml. sterile isotonic Darrow's solution, coloured with Evan's blue and containing 500 units of Heparin, was set up at a height of 8 ft. This was connected by means of a three-way tap to a sterile glass tube set on a metre stick. This manometer was filled and stabilised. After puncture of the aorta, the adaptor was connected to the needle and a direct reading of the blood pressure made on the manometer. The result of this rather primitive method was not completely accurate but was sufficiently so to permit an estimation of the effect of injection. It was found that it gave in terms of mm./Hg. exactly the same reading as the systolic pressure obtained by the sphygmomanometer. There was a fluctuation of 0.5 cm. water.

The next experiment was designed to measure the rise of intra-aortic pressure resulting from the injection of 20 ml. fluid.

The radiographic results of routine aortography show that the dye rises a variable distance up the aorta. This may be as much as 8 cm. There has not been any appreciable distension or ballooning of the aorta at any point as far as can be seen by X-Rays. Whether the pressure required to deliver such a quantity through a small needle is known or not, it is not possible to estimate theoretically any intra-arterial rise. Unlike a problem of pure physics many other factors are involved, such as the tone and elasticity of the vessel wall, peripheral resistance and the effect of a moving column of heavy fluid. There remained only the practical experiment described below.

Experiment II.

A Darrow's solution manometer was set up and stabilised. A No. 16 S.W.G. needle was inserted lower than the usual position and placed so that the needle point lay centrally in the aorta at the level of the middle of the body of the 2nd lumbar vertebra. The three-way adaptor was connected and the heparinised Darrow's solution dripped through it.

A second No. 16 S.W.G. needle was then introduced

in the usual position so that it lay exactly at the upper border of the second lumbar vertebral body. The distance in the aorta between the two needles was approximately 2 cm.

The manometer was re-connected to the lower needle and injection made through the upper meedle.

The rise in the manometer following injection was 0.5 cm. H20.

There are certain obvious fallacies in such an experiment. The rise in intra-aortic pressure is sudden and not sustained, the water-type of manometer does not accurately measure such sudden rises and there is undoubted "damping" due to the inertia of the fluid column. Nevertheless, allowing for such discrepancies, the importance of the experiment was to demonstrate practically what had been suspected theoretically - namely that the rise in pressure was not significant.

Comparison having been made between aortic and brachial pressure and the rise in aortic pressure after injection by means of the water manometer, attention was now turned to the more accurate measurements by elector-manometer.

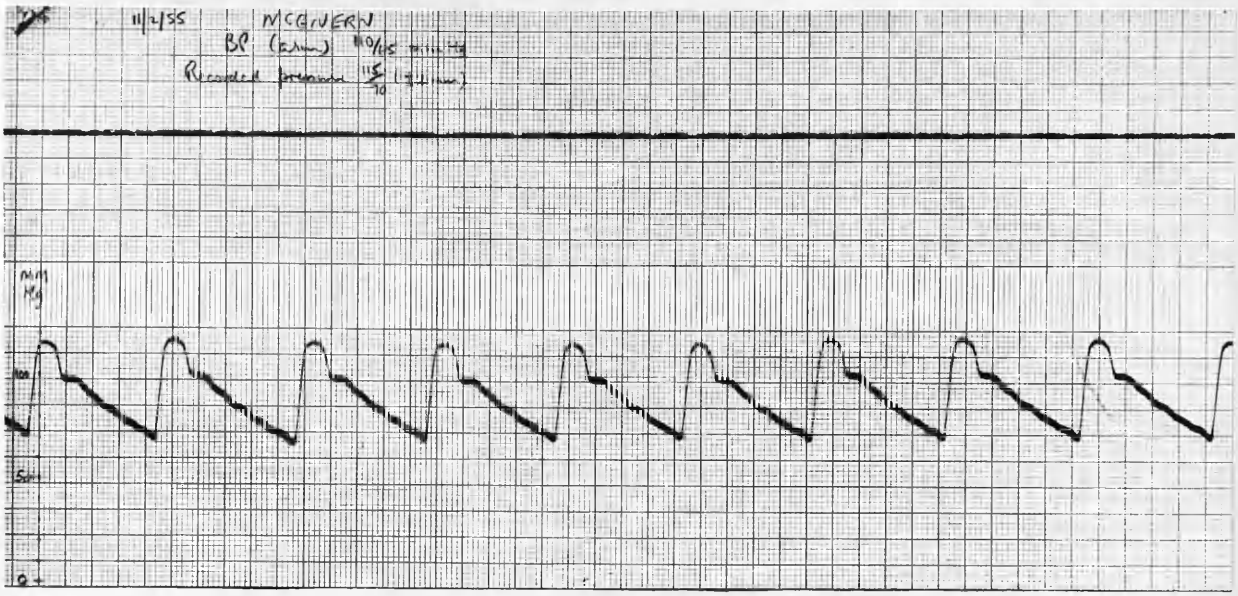
Experiment III.

Aortic puncture was carried out in the usual fashion at the level of the superior mesenteric artery. When the

needle was judged to be properly in position a drip of Darrow's solution was started. When the electro-manometer had been stabilised the catheter tubing was attached to the three-way tap. When this was turned so that the blood and fluid in the catheter were in contact a direct tracing could be made of the intra-aortic blood pressure at the level of puncture.

At the same time as this tracing was being made an estimation of the brachial pulse pressure was made by the sphygmomanometer. There was little appreciable difference between them, not exceeding in any case 5 mm./Hg. - the aortic pressure being the higher of the two.

Graph I below shows the tracing obtained.



GRAPH I. NORMAL AORTIC PRESSURE.

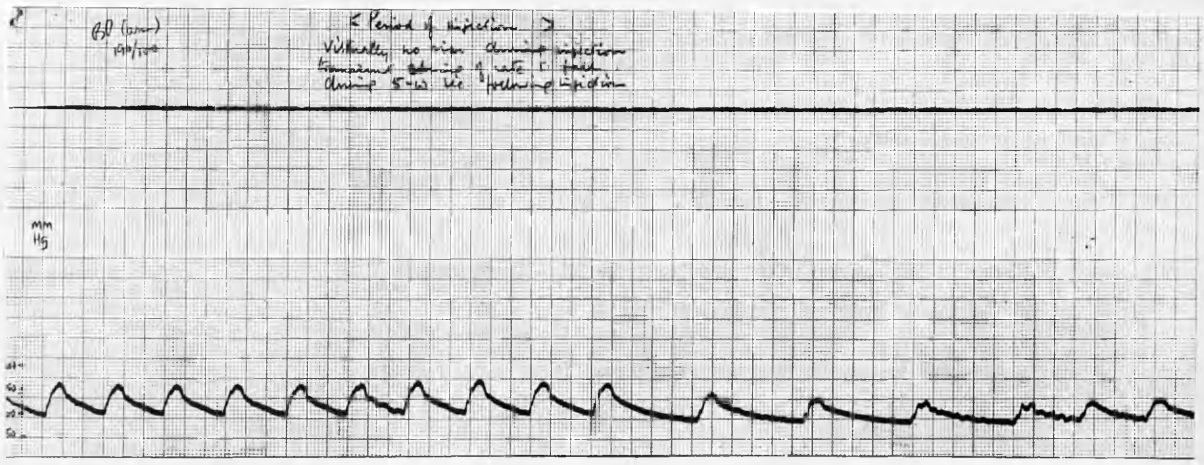
It is a typical arterial pulse pressure tracing and differs in no way from those obtained elsewhere in the body. Its only interest is that to my knowledge this is the first occasion on which a direct record of the aortic pressure at that level has been obtained in the human subject.

It is seen that the aortic pressure is recorded in this patient as 115/70 whilst that of the brachial pressure is 110/65 mm./Hg. This slight variation appears to be fairly constant as recordings made on three other patients gave similar results.

In order to confirm the findings of the previous experiment regarding the rise in aortic pressure following forcible injection, a similar technique to that described in experiment II was used. Two needles were inserted into the aorta. The lower needle was connected to the drip and saline perfusion by syringe carried out through the upper one. The electro-manometer catheter was then connected and stabilised to the lower needle and a tracing taken. Forcible injection was then carried out through the upper needle. The pressure tracing, Graph II on the following page, shows little appreciable rise in the intra-aortic pressure.

It will be seen that there is a rise in pressure not greater than 5 mm./Hg. This slight increase was followed by a slowing of the rate and a fall in pressure from 190 mm. to

150 mm./Hg. over 5-10 sec. after injection. The latter effect is common following the injection of fluid into an artery and is of no significance.



GRAPH II. AORTIC PRESSURE FOLLOWING INJECTION

One criticism which may be levelled at this experiment is that owing to the direction of the needles and the retrograde flow of dye up the aorta away from the lower needle, the rise in pressure would be maximal above the upper needle. This may not be fully transmitted to the lower needle. Even accepting this however, one important point emerged, namely, the rise in aortic pressure which was transmitted to the lower needle is the rise in pressure which will be transmitted to the aortic branches below the site of injection. This was thought to be of some importance when

considering the pressure transmitted to the renal arteries.

In order to determine the effect on the aortic pressure above the site of injection, two further recordings were taken.

In these instances, forcible injection was made through the lower needle and tracings taken from the upper one. Again there was little appreciable rise not exceeding 10 mm./Hg. in either case. The importance of this is obvious.

If forcible injection does not produce a rise anywhere in the aorta comparable to that occurring normally in sudden stress or emotion, it is highly improbable that it can in any way be injurious to any patient.

EFFECT ON CARDIAC CYCLE.

A further investigation seemed necessary when the radiological results of aortography with forcible injection were assessed. It will be seen on many of the films that there is retrograde spread of the dye up the aorta. This may be seen to extend as far as 8 cm.

Whilst the whole volume of the aorta was outlined it was obvious that this was effected by spread and dilution

of the dye from a thin jet and not from the complete arrest of the aortic flow or by a column of dye of that calibre. Nevertheless, it was not known what effect such a forcible retrograde spread would have on the cardiac cycle.

The most accurate method by which such changes may be recorded is by electro-cardiography.

Experiment IV.

Several patients had E.C.G. tracings carried out. These were done simultaneously with the pressure recordings described in the previous experiments. In no case was any alteration seen on the electro-cardiogram.

These experiments confirmed the clinical observation that no appreciable change was detected in the radial pulse or heart beat. The use of forcible injection such as has been described does not have any detectable disturbing effect, transient or permanent, on the heart muscle.

INJECTOR PRESSURE.

Consideration of the injector suggested that the pressure which could be obtained by it on purely mechanical

grounds was very great. What seemed to be important, however, was not the maximum pressure obtainable, but the pressure actually used in introducing the dye.

It was found quite impossible even to determine this latter pressure by means of a water manometer - it would have taken at least 40 ft. of water to do so. In the same way it could not be investigated by the electro-manometer, which is not intended for great pressure.

A simple mercury manometer was fashioned, allowing a reading up to 150 cm.

Experiment V.

The syringe and tubing filled with water was connected to the straight arm of a Y tube. To one of the branches a No. 16 S.W.G. needle was connected whilst the manometer was connected to the other. When injection of 20 ml. was made in 0.75 sec. a maximum pressure of 800 mm./Hg. was recorded. When a similar injection was made in 1 sec. through a No. 18 S.W.G. needle, the pressure registered was 900 mm./Hg. It is of course quite possible to raise this pressure further by the immense lever advantage which will provide more rapid injection.

When a similar experiment was carried out using manual pressure, it was found that injection of 20 ml. of water through a No. 16. S.W.G. needle could not be done in

less than 3.5 sec. This produced a pressure of 500 mm./Hg. A similar injection through a No. 18 S.W.G. needle recorded a pressure of 600 mm./Hg.

A pressure of 800-900 mm./Hg. over 1 sec. produced by an injector is not excessive compared with a pressure of 500-600 mm./Hg. by manual injection, sustained over 3-6 sec.

Certain basic factors must not be ignored. The pressure although high is being exerted by a very thin stream into an expansile column greatly in excess of it. It is entering tangentially against a moving column of heavy fluid with its own degree of pressure. The effect of velocity has already been shown to be negligible and finally practical experiment has demonstrated that the introduction of a small quantity of fluid such as is used does not materially raise the pressure in the aorta. No radiological ballooning of any segment of the aorta has been seen and no ill effect has been noted in any patient.

It is felt therefore, that the forcible injection of dye carried out by this technique is a safe procedure and that its use is justified by the results.

PRESSURE TRANSMITTED TO RENAL ARTERIES.

Reference has been made to the possibility of transmitted pressure to the renal arteries. The results of the previous experiments suggest that it cannot be very great but it was considered advisable to investigate and verify this point.

The only way by which any rise in pressure could be determined was to take a direct reading from the renal artery whilst injection was being made into the aorta.

The accurate blind puncture by needle of a renal artery is impossible. It was therefore deemed absolutely necessary to carry out puncture of the renal artery under direct vision during operation. Further, it was not justifiable to prejudice a patient in any way so it was decided to carry out this experiment only where the kidney was being removed. As both the aortic and renal artery punctures were being done under direct vision, the left kidney was the obvious choice.

Accordingly a patient with left renal calculi, in whom nephrectomy was necessary, was selected.

Experiment VI.

At operation, a No. 16 S.W.G. needle was inserted into the left renal artery so that the point lay almost at

its junction with the aorta. This needle was connected to the manometer.

A similar needle was inserted into the aorta under vision, 1 cm. above the first one, and with the point directed downwards.

The usual rapid injection of 20 ml. Darrow's solution was made.

The reason for directing the point of the upper needle down towards the renal arteries was to obtain the maximum pressure by using the normal direction of the blood flow.

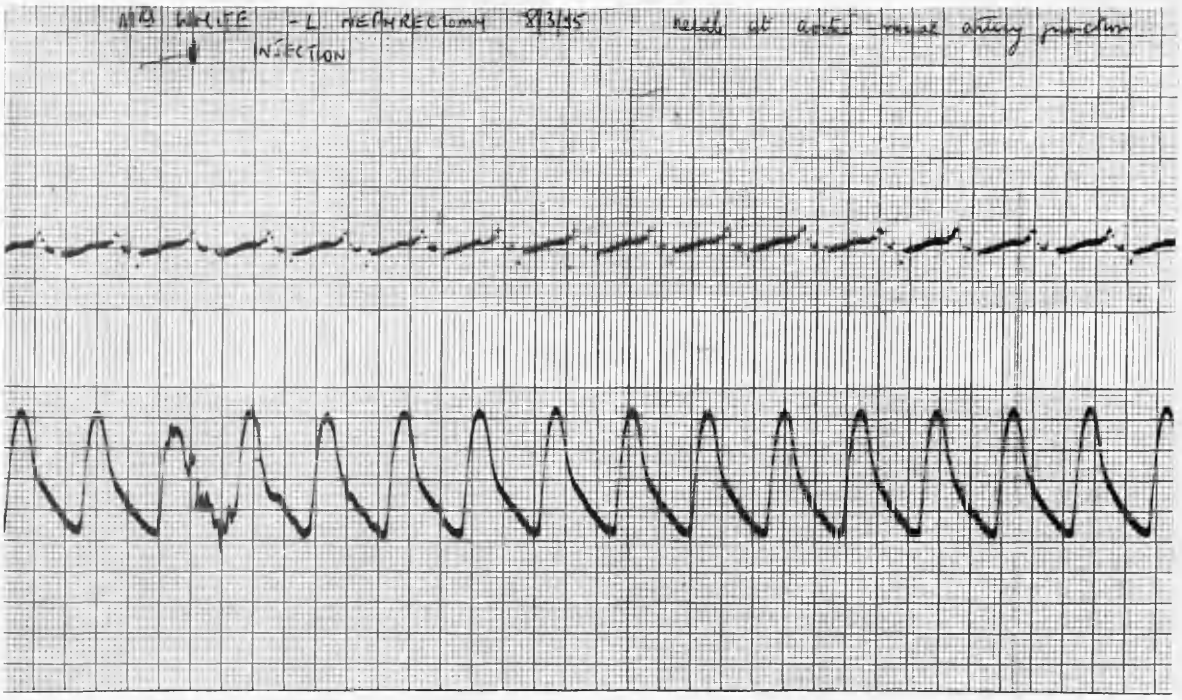
In actual practice the needle is always directed upwards and injection made against the aortic stream. Thus no matter whether the point of the needle lies above or below the renal arteries this maximum pressure will not be attained.

This does not include instances in which the whole injection is made into one branch of the aorta.

Graph III on the following page is that obtained in this experiment.

It is seen that after injection into the aorta there is a very slight rise of 5 mm./Hg. in the pressure in the renal artery. In this case there is no slowing of the rate or fall in the pressure in that artery.

The electro-cardiograms taken during and after



GRAPH III. RENAL ARTERY PRESSURE FOLLOWING INJECTION.

show no change from those taken prior to injection.

One of the main reasons for determining the rise of intra-aortic pressure and the pressure transmitted to the kidneys arose out of the work of Byrom and Dodson. (1948)

This was in connection with the effect on the kidneys of a sudden rise of intra-aortic pressure. This had not previously been done on the human and it was felt that such an investigation was worthy of attention to exclude any criticism of aortography in the light of their results.

In a study of the causes and effects of hypertension Byrom and Dodson carried out numerous experiments on rats as follows:-

A cannula was tied into the left carotid artery, the point towards the heart. Rapid injection of 2 ml. Ringer's solution was made some 15-20 times. The rise in aortic pressure following this was between 80 and 90 mm./Hg. recorded by a mercury manometer. During each injection the cortex of the kidney was seen to blanch and histological examination of the kidneys later showed a necrotising arteritis. This affected almost 50% of the animals and was marked in the arcuate, interlobular and afferent glomular vessels. When one renal artery was temporarily occluded the kidney did not show such changes.

The conclusion reached was that brief artificial over-distension of the arterial tree in the normal rat causes typical focal arterial necrosis, the smaller arteries of the kidney being selectively vulnerable.

This valuable experimental study appeared at first sight to offer serious criticism to the employment of aortography particularly where pressure injection is made.

On several grounds, however, the comparison is not exact.

As a result of personal experiment, it may be stated:-

(1) The capacity of the aorta of a rat from the carotid artery to the renal arteries is 0.5 ml. The forcible introduction of 2 ml. of fluid increases that capacity 400%. The capacity of the average human aorta over the same distance is 110 ml. and the introduction of 20 ml. increases the capacity less than 20%.

(2) The considerable rise in pressure in the rat - 80-90 mm./Hg. is probably due to the excess filling and is more a reflection of the pressure used in injection which was not stated. In man, as has been described, the rise of pressure in the aorta is not more than 10 mm./Hg. of which only a fraction is transmitted to the renal arteries.

(3) The production of arterial necrosis in 50% of the rats required numerous (15-20) repeated injections, whereas in aortography one or perhaps two injections only are made.

(4) Finally, practical proof is afforded by the absence of necrotising arteritis in kidneys removed from patients who had undergone aortography.

It is considered justifiable to affirm that the danger of producing lesions in the human kidney as a result of aortography comparable to the findings of Byrom and Dodson in the rat may be discounted.

INJECTION INTO ONE BRANCH.

There remains the question of the effect of both pressure and velocity on one of the aortic branches should the needle be placed exactly opposite its origin.

Three vessels only may be affected in this way, the coeliac, superior mesenteric and right renal.

The greatest effect shown radiologically appears to be when injection is made into the last named vessel.

Diodrast clearance tests suggest that there is a total renal blood flow of 900-1300 ml. per min. in relation to a standard surface area of 1.73 sq. metres. (Applied Physiology. Samson Wright, 1952.)

If equal function of the kidneys is accepted, the flow through one kidney is some 7-12 ml. per sec. The introduction of 10-15 ml. produces a sudden rise of volume to double the normal amount. This results in flooding of the kidney by the medium.

Whilst such an event is undesirable, the extensive arterial tree and vast capillary network, much of it in reserve, appear to cope adequately with this increase in volume and pressure.

Much of what has been said regarding velocity and pressure still applies in these cases. In addition the needle does not by any means totally occlude these vessels

even if it enters the lumen. For example, the average diameter of the right renal artery is 8 mm. whereas that of the largest needle used is 1.5 mm.

In my experience, the injection of quantities of dye up to 18 ml. into one aortic branch has not been attended by any ill effect. It is only fair at this stage, however, to mention that there are four references in the literature to the adverse results from such an injection. Detailed references will be made to this when the hazards of aortography are discussed. In this respect, I consider that damage may result to the affected organs, as much from toxicity of the concentrated medium as the mechanical effect of reasonable pressure.

Nevertheless, further experimental work was carried out to obviate such a mishap. This consisted of the use of a different kind of needle. I had made for me two such types.

The first contained a long lateral opening behind the bevelled end which was "blocked off".

The second type was similar but with several smaller openings set around the circumference.

In this way the projection of a stream of dye in the axis of the needle was avoided and so prevented injection directly into any single branch of the aorta.

In practice, such needles did not prove satisfactory for two reasons.

In spite of the openings having a larger surface area than that of the end of the usual type of needle the resistance was greater.

More important, such openings did not permit a free retrograde flow of blood and it was not easy to be sure of the correct position of the needle. Further, it was possible for one of the openings to lie outwith the aortic lumen and so increase the possibility of extravasation. This did, in fact, occur in one case.

For these reasons the idea was abandoned and a return made to the usual type of needle.

CONCLUSIONS REGARDING THE USE OF MECHANICAL FORCIBLE INJECTION.

(1) Velocity.

The results of the experiments carried out on the effect of the velocity of a thin stream of dye show that no damage can be attributed to it. There are sound physical and anatomical grounds for believing that this is the case not only in the aorta but also should the dye be injected directly into one branch.

(2) Aortic Pressure.

In spite of the considerable pressure used to inject 15-18 ml. in 1 sec. there is little appreciable rise in the intra-aortic pressure 1-2 cm. above or below the site of injection. There is no radiological evidence of aortic distension at that point. The transmission of a small rise in pressure such as 5-10 mm./Hg. is of no importance either in the aorta or any of its branches.

The forcible injection of dye into the aorta and its effect on the aortic pressure do not cause any changes in the cardiac cycle recordable by E.C.G.

(3) Injection wholly into one branch.

This is a possibility which may occur particularly where there is any abnormality in the site of origin of the aortic branches. Under "normal" anatomical conditions with a properly positioned needle it will not occur because both the coeliac axis and superior mesenteric arteries lie anterior to the line of the needle whilst the right renal artery lies posterior to it. Except where puncture is made through the juncture of aorta and left renal artery, injection cannot be made into the latter.

It cannot be denied, however, on purely mechanical grounds, that the greater the pressure where the whole content is discharged into one branch the greater the possibility of

morbidity. This, however, is also dependent on the quantity and type of medium used. No ill effect has resulted in the present series.

Where doubt concerning the position of the needle point, or the presence of anomalous renal blood supply exists, it is possible to check this by a preliminary injection of a small quantity of dye before proceeding with the full injection under pressure.

(4) Extravasation.

The use of forcible injection may be thought to produce a greater degree of extravasation than by ordinary hand pressure. This is largely dependent on the amount injected rather than on the degree of pressure used.

Extravasation may be due to faulty initial positioning of the needle. Under these circumstances it will occur no matter how the dye is introduced. Where extravasation results from dislodgement of the needle due to movement during injection it has been my experience that this is much more liable to happen with manual injection and manoeuvres than with the use of a solid injector apparatus.

Accidents attributable to mechanical faults in forcible injection apparatus could only occur when compressed air of a "gas machine" was used. No such accident has ever been published but the technique which I use does not allow

any such mishap to occur.

(5) Multiplicity of Vessels.

Reference is made elsewhere to the criticism that forcible injection may outline too many vessels and obscure the vascular detail of the desired area. Such is not the case. The greatly increased detail renders interpretation easier.

It is my opinion, based on an experience of one hundred and fifty cases, that pressure injection is quicker, easier and safer than manual pressure, both for the patient and the operator.

TECHNIQUE.

ANAESTHESIA.

The examination may be carried out under general or local anaesthesia or a combination of these.

The latter appears to be the method used in certain American clinics and conforms to the technique previously mentioned for peripheral arteriography recommended by Brooks.

I see no advantage in submitting the patient to local anaesthesia and then instituting general anaesthesia after puncture but before injection of the dye.

Local anaesthesia would appear to have certain disadvantages. Even after adequate infiltration with the anaesthetic solution the impingement of the needle against the vertebral body can be painful. There may be quite severe discomfort when the aortic wall is punctured and the necessary rapid injection of any of the recognised media may well occasion an intense burning sensation throughout the abdomen. The pain caused may result in involuntary muscle movement and this in turn may lead to the needle being dislodged. Should severe cramping movement occur it is not impossible that actual scarification or even tearing of the aortic wall may result. The apparent advantage of having the complete co-operation of the patient, particularly in respect of control of respiratory

movement is quite unreliable.

In the present series one patient only (Case 50) was examined under local anaesthesia. This patient was most co-operative but it was obvious that some acute discomfort was felt and severe involuntary inspiration took place after injection.

I therefore prefer the examination to take place under general anaesthesia which seems to be more satisfactory both for the patient and the operator. The only disadvantage lies in the slightly greater risk of general anaesthesia. The complete arrest of respiratory movement can easily be obtained by the intravenous injection of one of the relaxant drugs such as Succinyl Choline.

The routine procedure used is premedication by Omnopon gr. 1/3 and Scopolamine gr. 1/150. Soluble Thiopentone is used for induction followed by intubation. The patient is turned to the prone position and anaesthesia continued with Nitrous Oxide or Cyclopropane. After the needle has been inserted into the aorta Succinyl Choline is injected intravenously. The usual dose is 2 ml.

After the fibrillary twitchings have ceased and complete paralysis obtained (5-10 sec. after injection) the dye is introduced into the aorta.

One additional advantage of general anaesthesia is that the blood pressure level may be more easily controlled

than during local anaesthesia. The density of the nephrogram phase (which will be explained later) is maximal with a systolic pressure between 90-100 mm./Hg. It is important, however, to make sure that the pressure does not fall too low as renal excretion ceases below 70 mm./Hg.

APPARATUS.

The necessary equipment consists of the following:-

Needles

Three sizes of needles should be available.

(1) No. 16 S.W.G. (Ext. diam. 1.5 mm.; int. diam. 1.0 mm.) 15 cm. long for use in adults.

(2) No. 18 S.W.G. (Ext. diam. 1.25 mm.; int. diam. 0.8 mm.) 15 cm. long for use in adolescents or suspected vascular disease.

(3) No. 20 S.W.G. (Ext. diam. 1.0 mm.; int. diam. 0.6 mm.) 10 cm. long for use in children.

These needles should all have filled stylets and Luer-Lok mountings.

Syringes

Syringes.

Two 20 ml. all-glass syringes with metal Luer-Lok nozzles.

Tubing

Special rubber pressure tubing with an additional woven sheath - 21" long.

Adaptors.

A three-way Luer-Lok adaptor may be useful but is not necessary unless experimental work or further injections are to be carried out.

One blind single adaptor for application to the tubing.

It has been found convenient in practice to have the above equipment together with surgical gloves, towels, swabs containers and Anaesthetist's armamentarium included in one drum so that the set may be autoclaved together and be available complete.

Injector

This has already been described.

Medium

Sodium Acetrizoate 70% is the opaque medium of choice. Diodone preparations may be used but are not quite as satisfactory. There is now no place for Sodium Iodide in aortography.

PROCEDURE.

The syringe and tubing filled with the medium, previously warmed to blood heat, is fitted to the injector and the blind adaptor applied to prevent leakage. The other syringe may be filled with sterile saline solution so that perfusion may be carried out if desired.

It is imperative that the patient be given a test dose of the medium to be used before proceeding further. Reliance should not be placed on a previous uneventful excretion urogram as a different strength if not a different drug may have been used.

This test dose may be given any time previously on the day of examination but it has been found expedient to have it given by the Anaesthetist before induction of anaesthesia and so prevent wastage.

After anaesthesia the patient is placed prone on the X-Ray table and a preliminary film taken to check position, exposure and timing. It has been found useful to confirm the presence of twelve ribs and the level of the 1st. lumbar vertebral body by incorporating in this film a small lead marker which is subsequently removed.

The area is then cleaned and draped and puncture carried out under aseptic precautions as follows:-

The needle is inserted through the skin just below

the left twelfth rib, a distance of 8 cm. (four finger breadths) from the midline of the spinous processes. It is directed upwards, forwards and medially in the direction of the first lumbar vertebra. When the needle is felt to impinge on the vertebral body it is withdrawn some 2 cm. to clear the fibres of the left crus of the diaphragm. The stylet is withdrawn and the needle advanced more ventrally. Eventually the needle slides past the left antero-lateral aspect of the vertebra and enters the aorta. As it passes through the wall of the aorta it imparts a sensation similar to but more pronounced than that felt on thecal puncture.

It will be appreciated that there is some variation in the depth at which the needle enters the aorta, depending on the size and build of the patient. The average depth, however, has been found to be 12 cm. from the point of the needle.

The preliminary striking of the vertebral body is regarded as an essential step for two reasons.

First, it is the surest way of placing the needle near the centre of the aortic lumen. If the approach is more lateral and "first time" puncture attempted there is a greater risk of transfixing the walls of the aorta.

Second, it more surely avoids possible damage to intra-abdominal organs.

The approach should be slow, sure and deliberate.

When blood is seen coming from the needle the latter is rotated through 360 degrees to ensure that it lies freely in the lumen of the aorta.

In the case of a No. 16 needle there is a pulsating stream of blood. The finer needles produce a rapid drip.

After the needle has been properly placed, with the bevel facing upwards, the rotary tubes of the X-Ray machine are started, the tubing is carefully connected and rapid injection is made.

I aim to inject 15 ml. in not more than 1 sec. Immediately after the first exposure is made, the cassette is changed as rapidly as possible and the next exposure made. This is repeated. The average time taken to do this is about 4 sec. so that the films taken are - immediate, 4 sec. and 8 sec.

The needle is then removed.

Further films may be taken at 2 min. intervals if excretion urograms are required.

In the event of a second injection of dye being required it is important to prevent clotting of blood in the needle and so obviate a second puncture. During the time the films are being developed and preparations being made perfusion with saline or citrate solution may be carried out or more simply, the stylet replaced within the needle.

ALTERNATIVE METHODS.

Alternative techniques used in aortography consist of the injection of dye through a catheter passed up the aorta to the required level from an accessible branch below.

In 1941, Farinas first described this approach. The femoral artery was exposed under local anaesthesia and a long catheter fed up the aorta via the external iliac to the level of the renal arteries.

In order to avoid damage to the femoral artery an alternative approach using the lateral femoral circumflex branch of the profunda femoris artery was proposed by Goodwin, Scardino and Scott in 1950. These techniques, however, were somewhat tedious and were shortly displaced by the percutaneous puncture of the femoral artery with a trocar. This was subsequently followed by the passage of a polythene catheter described by Pierce in 1951. This was also the method used by Abeshouse and his colleagues in the same year.

Whilst I have no personal experience of these methods they have, in my opinion, certain disadvantages. The translumbar puncture of the aorta is simple, quick and free from serious hazard. The dissection and puncture of the femoral artery is not free from sequelae such as thrombosis. The retrograde passage of a catheter is not always simple and repeated X-Ray exposures may be necessary to confirm the

position of the catheter.

Even with the percutaneous method sequelae are not infrequent. Whilst this method is used commonly to determine the state of vessels below the femoral artery and is not associated with appreciable morbidity this does not apply where a retrograde catheter is passed. Under these circumstances a much larger bore trocar is used than in peripheral arteriography and there is an appreciable number of cases of haematoma formation. The actual trocar used to permit the passage of a catheter is much larger than any needle used in translumbar aortography. When comparison is made between the size of the femoral artery and the aorta the relative size of the trocar is considerably greater. The trauma inflicted by the catheter is therefore much greater than that caused by the translumbar needle.

I have been informed of two cases where a serious traumatic lesion of the aortic wall was caused by the tubing, resulting in the development of a complete obstruction in the aorta below the site of the damage.

Finally, the published photographs of aortograms and more particularly renal arteriograms do not impress me as being equivalent to the results obtained by translumbar puncture using the technique which I have devised.

Abeshouse and his colleagues, in the light of their experience both with the retrograde and translumbar methods,

state that the latter is quicker and easier. They suggest that the retrograde method be reserved for cases of aortic aneurysm on the assumption that this approach is safer in that condition.

I am by no means convinced that such is the case. It is frequently possible to determine the approximate level of a suspected aneurysm by other methods, clinical and radiological. Translumbar puncture may then be performed quite safely above that level as was done in three cases of abdominal aneurysm in this series.

INTERPRETATION.

The interpretation of a translumbar aortogram requires a complete knowledge of the anatomy of the abdominal aorta and its branches. Before making a detailed study of the arteriogram to be interpreted it is essential to identify and trace to its origin from the aorta each vessel shown. Thus only may the exact anatomical relationship be established.

The ideal picture in which to study a particular branch of the aorta is one which shows only that vessel and a short segment of the aorta with no other branch outlined. This is impossible in practice.

Mention has already been made of the appearances of one hundred aortograms which show the impracticability of absolute accuracy in positioning the needle just above the renal artery. This objection is sustained in relation to other vessels. In addition to this there are many other considerations which may influence the number of vessels affected and the length of the aorta outlined. This is largely dependent on the angle of the needle and the amount and rate of injection of the medium. Thus it is that in almost every case vessels other than those particularly desired are filled and may overlie those which are to be examined.

Mention has also been made that forcible mechanical

injection does not necessarily increase the number and extent of other branches compared with the pictures obtained by hand pressure.

Even when this does occur, the greatly increased density of all vessels and the much higher proportion of success in demonstrating the required vessel more than compensate for any such criticism of this technique.

The greater the intensity and sharpness of the arteriogram the easier the interpretation.

When injection is made for renal arteriography at the level of the 1st lumbar vertebral body many branches of the aorta may be visualised.

Before making a detailed consideration of the renal arteries some comment will be made concerning the other vessels which may interfere with the easy recognition and interpretation of the vascular supply to the kidneys.

The phrenic arteries are seldom seen. They are small vessels with a variable origin and they do not seem to fill up well. In the few cases where they do show up they do not cause any difficulty in the interpretation of the renal blood supply because they have an almost vertical course and lie above the vascular pattern of the kidney.

The coeliac axis is frequently seen in whole or in part. It shows considerable variation in its level, type of

origin and course but in the beginning it is a large vessel which attracts the dye in a concentration similar to that of the aorta at that level. In the "normal" patient the coeliac is a short stump which soon divides into three branches - the left gastric, hepatic and splenic. In some cases, however, this common trunk may continue for some distance before branching.

The left gastric artery is the smallest division and has, to begin with, an almost vertical course. It seldom appears on arteriography and my impression is that this failure to fill well is due to its size and the haemodynamics of its vertical course. Neither this artery nor its terminal branches have given rise to any confusion of interpretation in the present series.

The splenic artery, which is usually the largest division of the coeliac axis, frequently presents in whole or in part. It is a thick and sometimes tortuous vessel running up to the left side of the abdomen. In its course to the spleen it may dip down below the level of the left renal artery. It may loop on itself or divide close to the aorta and run out as two large vessels.

The short branches of the splenic artery are seldom if ever seen but where the entire vessel is filled the left gastro-epiploic vessel may be discerned. The terminal branches of the main artery within the spleen are variable - sometimes

presenting a regular dichotomy of diminishing calibre, sometimes resembling a whorl of vessels.

To the inexperienced eye the splenic artery and its terminations may at first appear easily confused with the left renal artery. Certainly it shows up frequently and may overlie the renal blood supply both within and outside the kidney. This is particularly the case where there is any splenic engorgement. Nevertheless, there are several distinguishing features about it. In spite of its proximity to the renal artery its origin is always identifiable and it can confidently be traced along its tortuous course. There is an absence of branches from it until far out from the aorta. The terminal branches do not resemble those of the kidney which are quite distinctive and they lie much higher in the abdomen and further out than the renal mass.

The other terminal division of the coeliac is the hepatic, frequently seen but not so commonly as the splenic. It divides just beyond the right edge of the vertebral column into its several branches and there may overlie the vessels of the right kidney. After division into hepatic and gastro-duodenal arteries, usually of about equal size, the hepatic artery continues upwards and runs above the upper pole of the right kidney and medial to it before terminating in numerous smaller branches in the liver.

The right gastric artery is not usually well filled

and peters out before descending to run medially away from the kidney.

The right gastro-duodenal does descend over the right renal artery but even when it is quite well outlined it has a course which crosses the renal vessels and should not be confused with them.

Reference to Fig. (7) shows the true course of the coeliac branches in the living patient. This picture was obtained by injection wholly into the coeliac trunk.

The superior mesenteric artery is a large trunk arising like the coeliac from the anterior aspect of the aorta. whilst it usually comes off a short distance above the renal arteries its origin may on occasion lie almost alongside them and it is not surprising that it is usually filled to some extent. The vertical course downwards of the main trunk either to the right (40%) or to the left (60%) of the midline does not occasion any difficulty in interpretation. The branches from it do not resemble those from the renal artery at all. In the upper abdomen these branches are long vessels finally anastomosing with each other well below the renal substance. Where there is enlargement downwards of the kidney, the mesenteric branches may overlie the lower pole but may be seen to extend beyond the parenchyma of the kidney and are easily traced out to their end distribution.

The suprarenal arteries like the phrenics do not

usually show up well. They are somewhat variable in number, origin and size. In addition to this the vascularity of these glands is not constant but dependent on the activity of the gland which varies according to circumstances. Further reference to this will be made when lesions affecting the adrenal gland are considered.

The lumbar arteries are easily identifiable. They arise from the lateral aspect of the aorta on each side and run out transversely as far as the lateral border of the vertebral bodies, at which point they turn posteriorly between the transverse processes. This angle gives the appearance of an abrupt termination and is quite unmistakable.

The testicular arteries are only occasionally seen, usually on the right side as slender vessels. They run out transversely as far as the tip of the transverse process at their level of origin. Thereafter they pursue a vertical downward course. (Fig. 24)

This transverse and then vertical angle had not previously been appreciated as the usual anatomical description (Gray's Anatomy, 1945) is that the course is obliquely down from the aorta.

The inferior mesenteric artery is not usually well outlined. Even when the entire extent of the abdominal aorta is filled and the iliac vessels are clearly seen, the inferior mesenteric is not completely visualised. It is best seen

when low aortic puncture is performed for delineation of the iliac vessels in peripheral vascular disease. In these cases it does not interfere with the detail of the lower aorta or its terminal branches.

Occasionally, the deep epigastric arteries are seen running up into the abdomen. This is very uncommon, however, and only appears following low aortography.

THE RENAL BLOOD SUPPLY.

1. Renal Arteriogram.

The renal arteries usually arise from the aorta at a level between the lower border of the 1st and the upper border of the 2nd lumbar vertebrae. (Fig. 1)

Close to the aorta the arteries run out almost at right angles but with a slight inclination downwards. This downward direction is continued towards the hilum of the kidney but it should be remembered that this angle may be appreciably altered by the normal renal movement occurring during diaphragmatic excursion from respiratory movement.

In most cases the first division of the main artery takes place close to the hilum of the kidney and from there these divisions run into the substance of the kidney. From these divisions arise the lobar branches from which are given off at acute angles the interlobar branches. These run up between the pyramids and end in graceful curving branches - the arcuate arteries.

Finally from these arteries the fine interlobular arteries arise at right angles. These arteries are end arteries and there is no communication between them.

It is to the arrangement of the interlobar and arcuate arteries that the typical fan-shaped appearance on arteriography is due. No other vessels in the abdomen

present this appearance and the termination of the renal arteries is quite unmistakable.

The examination of a renal arteriogram should be systematic. Attention is turned first of all to the level at which the main artery leaves the aorta. If accessory vessels be present, the level of their origin is similarly noted. The size of the vessel at its origin and as far as the primary division is assessed and careful attention turned to any alteration in the calibre between these points. The distance from the aorta at which the primary divisions take place is measured and at the same time the relation of this point to the renal hilum is noted. If, as is frequently the case, the parenchymal outline of the kidney is not visible on this film, it may conveniently be compared with the following film which more clearly than any other will show the kidney substance. These primary branches are followed into the renal parenchyma and attention turned to their number and distribution to the various parts of the kidney.

In the same way the course and relationship of any accessory vessel should be carefully studied, particular care being directed to the point of entry into the kidney.

These relationships are of great importance when conservative surgical treatment of a kidney is contemplated.

Within the kidney the various smaller branches are followed to their termination.

The vascularity of the kidney is considerable but it is an even regular pattern of vessels of diminishing calibre ending in the graceful fan-shaped arrangement previously mentioned.

Any deviation from this on a successful arteriogram denotes some abnormality.

The first film, if taken fast enough, will show this arterial pattern only. If, however, it is taken slightly later the film will show the arterial tree with not quite so good definition and also the early nephrogram phase.

2. Nephrogram.

When the contrast medium used consists of one of the organic iodide compounds, further information is available concerning the kidneys. As the dye leaves the vessels which have shown up on the arteriogram it enters the tiny arterioles and begins to be eliminated by the renal tubules. This condensation of the dye in the capillaries and tubules produces on X-Ray a fairly dense shadow of the whole kidney substance. (Fig. 2) To this the name "nephrogram" has been given.

The nephrogram represents the early excretory phase of the kidney and is a very valuable indication of the total functioning renal parenchyma. In some cases a distinction may be made between the cortical and medullary parts, the

former appearing somewhat more opaque. This distinction is more marked when the intravenous test dose has been administered some time before the examination. In the majority, however, the density is fairly even and is maximal 4-5 sec. after injection. This phase lasts up to several minutes, gradually decreasing as the dye leaves the small vessels and tubules to become concentrated in the distal tubules and calyces.

The interpretation of a nephrogram is simple but attention should be turned to certain features.

The outline of the parenchymal substance should be smooth and regular. Irregularity and "bossing" may be made out in conditions such as tuberculosis or pyelonephritis. In some cases the irregularity may be due to a persistence of foetal lobulation which in the absence of any other pathological lesion is of little clinical significance. Provided there is an adequate vascular supply, accurate information regarding the size of the kidney can be established.

An alteration of the density of any part of the nephrogram is significant of pathological change. Areas of relative translucency denote avascularity and non-function of that part. Areas of increased density denote increased vascularity and are usually due to tumour formation. In this respect it is important, if examining late nephrogram films not to confuse the normal condensation in the minor calyces

in the late excretory phase, with a pathological process.

The nephrogram phase may prove to be the most valuable diagnostic film in certain conditions.

3. Excretion Urogram.

Eventually, as the dye collects in the distal tubules, calyces and renal pelvis, a typical excretion urogram appears. (Fig. 3) This is just the same as that obtained by intravenous injection and requires no further description. It is a much slower process and requires an exposure of films at intervals of several minutes.

It is obvious that these three phases following aortic injection of dye - arteriogram, nephrogram and urogram are not absolutely distinct. They merge consecutively one into the other.

The information concerning the kidneys obtained by aortography is threefold. First, there is the degree and anatomical pattern of the blood supply, then the extent of functioning parenchyma and finally the function and anatomical detail of the calyces and pelvis. In the words of dos Santos "The anatomical pattern is superimposed on the physiological function."

HAZARDS.

HAEMORRHAGE

We have already referred in the historical section to the inherent dread of aortic haemorrhage and the association in the minds of most medical men that there might result a sudden massive bleeding similar to that from rupture of an aortic aneurysm. Also the results of animal experiments did little to relieve this anxiety.

Certain facts regarding the practical results of puncture in the human, however, must be given due prominence.

The aortic wall in man is a fairly thick and tough structure. The strong medial coat has a large elastic fibre element which has a remarkable self-sealing effect. This effect is enhanced by the track of the needle which penetrates the wall obliquely at an angle of 45°.

My experience is comparable to that of many other surgeons who have found that haemorrhage is not a serious factor provided a careful, accurate technique is used. No record of a patient dying from haemorrhage following aortic puncture has yet appeared in the world literature and several thousand cases of successful aortography have been reported.

In addition, I feel sure that there must be many instances in which the aorta was inadvertently punctured

during lumbar ganglion block. I have been unable to find any record of death from haemorrhage following that manoeuvre.

In order to assess the effect of puncture, Smith Rush & Evans (1952) submitted 49 moribund patients to it. Needle puncture was carried out 30 hours to 4 days before death.

All of these patients were examined at autopsy and in eight of them only, minimal bleeding around the aorta could be seen. In the remaining 41 cases no evidence could be seen of the puncture site. The series included seven cases of severe hypertension and in five cases puncture was carried out through an atheromatous plaque.

I have had the opportunity of examining at autopsy 5 patients who died subsequent to aortography.

In no case was it considered that the procedure contributed in any way to death.

In three of the patients, careful inspection of the aorta showed no evidence either on the external or internal coats of any mark due to the needle puncture. The cause of death and time after puncture were as follows:-

Case (32) died 6 days after aortography from a large renal adenocarcinoma with malignant deposits in both lungs and adrenals.

Case (38) died 12 days after puncture and 2 days after nephrectomy for sarcoma of the right kidney. Two punctures

were made as the first injection was followed by extravasation but no evidence of either puncture was seen.

Case (29) died 24 days after aortography and 2 days after operation for a perforated duodenal ulcer.

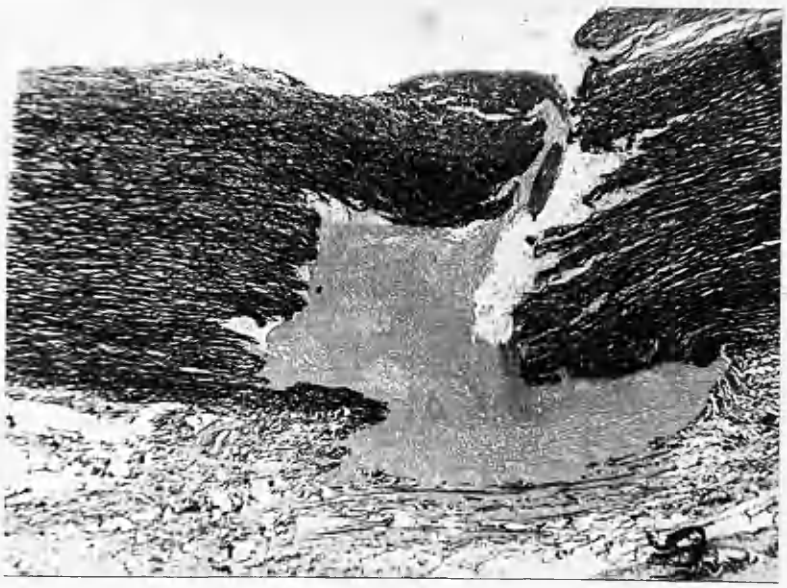
In the remaining two patients evidence of the puncture was seen in the intima and histological examination was carried out through this area. In neither of them, however, was there any naked eye evidence of the needle mark on the external coat.

The only published reference to the histological changes following aortic puncture is that of Wagner (1946). He examined an area of aorta through which puncture had been made seven months earlier and reported - "hyalinisation and fibrosis of aortic wall at probable site of aortic puncture."

Case (102) male aged 46, died 8 days after aortography. Autopsy showed bilateral renal tuberculosis and infiltrating carcinoma of the bladder.

Examination of the aorta showed no external evidence of puncture but a tiny scar was seen in the intima on the postero-lateral wall proximal to the orifice of the left renal artery.

Histological examination of this area shows (Section I) on the following page a track through the aortic wall



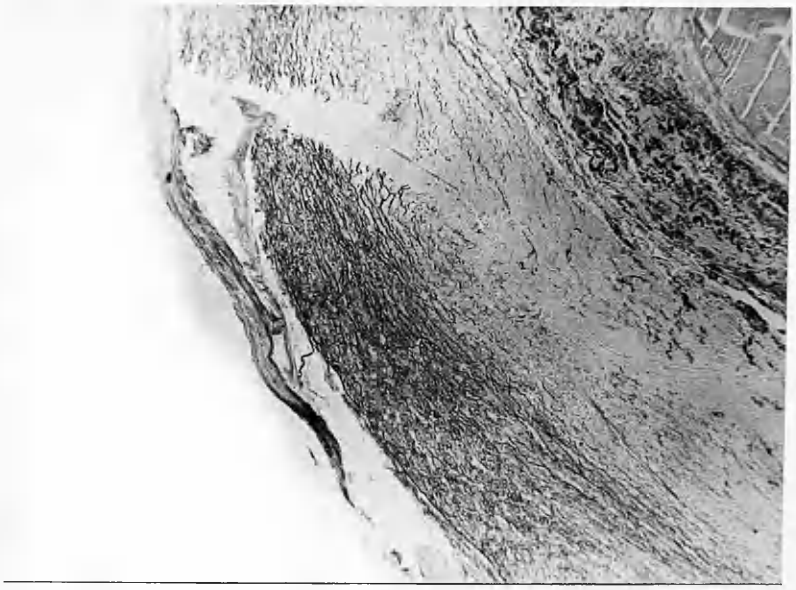
Section I.

Weigert's Elastic Stain x 50.

with interruption of the elastic fibres of the media. There is also some distraction of those connective tissue fibres of the adventitia adjacent to the media.

The track is plugged by a dense coagulum which consists largely of fibrin. There is no evidence of organization occurring from the media but early organization is seen in the adventitia.

Case (77) Female, aged 66, died 11 days after aortography. Death occurred from cardiac arrest during operation. At autopsy no evidence was seen on the external surface of the aorta of a puncture mark but a tiny scar was



Section II

Weigert's Elastic Stain X 40.

seen in the intima at the site of the puncture, confirmed by comparison with the aortogram.

Histologically (Section II) at the site of puncture there is a scar consisting of well-formed connective tissue which interrupts the elastic fibres of the media. There is no trace of a coagulum at any point in the track.

There is a striking difference in the histological appearances in these two cases. Organization and replacement of the coagulum by fibrous tissue is complete in Case (77) but hardly apparent in case (102) It is evident that the

additional period of three days is not sufficient to account for the considerable difference in the stage of healing. It is not unlikely that the presence of tuberculosis and carcinoma had a profound effect on tissue repair. It is felt that Case (77) is more truly representative of the normal course of events and the appearances of the arterial wall are similar to those described but not published by Crawford (1954) as occurring in the carotid arteries after puncture.

No further opportunity has arisen to confirm this.

The autopsy findings of these five patients confirm those of Smith and his colleagues that haemorrhage is not a feature of aortic puncture.

The other method of determining the presence of blood leakage from the aorta consists of the exposure of the area during operation. As the aorta and consequently any blood leakage is retro-peritoneal, assessment may be made during extra-peritoneal operations, such as exposure of the left kidney, ganglionectomy and the direct approach for vascular disease.

In the present series there have been 38 such operations. In each case a careful inspection of the region has been made and in four instances evidence of blood outside the aorta was found.

In three of these cases the blood was considered to have come from the aorta but in none of them did the quantity exceed an estimated leakage of 30 ml.

In two of these three some difficulty was encountered and a second puncture had to be made. In the fourth case I am of the opinion that it resulted from trauma to one of the lumbar veins and not from aortic leakage.

In no case could it be said that the presence of the extravasated blood rendered the operation more difficult or prejudiced the patient's treatment or recovery.

None of the patients in this series has shown any systemic signs or symptoms suggestive of bleeding such as elevation of temperature or local pain. I have been impressed by this - even the four patients with proof of bleeding at operation made no complaint at all.

The cases included a number in whom hypertension, arteriosclerosis and atheroma were present and these have not given rise to any anxiety regarding haemorrhage. Twelve patients had a systolic blood pressure in excess of 220 mm./Hg.

Whilst the dangers of serious haemorrhage appear to have been greatly exaggerated, this does not mean that a slow, careful, accurate technique can be neglected.

I have been informed of one fatal case (not published) in which haemorrhage was reported to have been the cause of death. No post mortem details are available but the patient

was receiving Heparin therapy following a disobliterative operation for peripheral vascular disease.

THROMBOSIS.

Vascular thrombosis has been responsible for at least two deaths following aortography. (Melick et al. 1952.) In each case, however, 20 ml. Sodium Iodide 80% was injected in toto, directly into the superior mesenteric artery. Reference has already been made to the necrotising effect of such a strong solution of pure Sodium Iodide which has no longer any place in arteriography. There is no evidence of the modern organic drugs causing death from thrombosis even when injected directly into the superior mesenteric artery of the human or dog.

I have, myself, on several occasions injected a considerable quantity of Acetrizoate into the superior mesenteric artery or coeliac axis without any upset.

The mechanical effects of forcible injection into one of the aortic branches, especially the renal artery, are discussed elsewhere.

ALLERGY

ALLERGY

Experience with aortography and urography suggests that sensitivity to the drug raises the most serious potential hazard. Whilst the modern organic iodide compounds are a great advance over Sodium Iodide they are by no means devoid of systemic ill effect. This is frequently noted in performing intravenous injection for excretion urography. It may take the form of any, or all, of the following signs and symptoms:- nausea, vomiting, flushing, conjunctivitis, urticaria, headache, respiratory distress, tachycardia or hypotension. Whilst such reactions although common are usually transitory and mild, they may be more serious and deaths have been recorded following intravenous injection.

On more than one occasion I have seen several serious side effects such as profound hypotension and vasomotor collapse.

There seems to be no reason to suppose that injection of a drug into the bloodstream via the aorta should be any more toxic than injection into the bloodstream via a vein.

In arteries, toxicity is inversely proportional to the capillary bed of the vessel injected. For example, the same dose is less toxic when injected into the aorta than when injected into the radial artery. Thus, apart from any possible effect on the abdominal organs, aortography is less serious than peripheral arteriography.

Comparison between intra-arterial and intravenous injection appears to show that the effect of the drug is greater on intravenous injection. It has been shown on more than one occasion (Opel, 1902: de Maurel, 1909) that cocaine injected into the aorta is ten times less toxic than cocaine injected into the vena cava.

Further it is recognised that too strong solutions should not be used for cerebral angiography as there is a risk of convulsions. Even allowing for the fact that there is a limit to the excretion rate of the drug by the kidneys, the concentration in the cerebral arteries must be lower, following aortic injection, than in carotid artery or intravenous injection.

In the description of the technique, the importance and necessity of carrying out a routine test dose of the drug has been stressed.

In one case, in my experience, there was quite a marked reaction to the test dose, consisting of widespread urticarial patches and wheals, increased salivation and some tachycardia. This reaction developed some ten minutes after test injection whilst the patient was under anaesthesia. This patient had an intravenous injection of 50% Acetrizoate one week previously, with no reaction. Aortography was therefore abandoned.

In two other cases a very mild reaction developed

some four minutes after test injection but before induction of anaesthesia. There was some doubt whether it was in fact a sensitivity reaction to the drug. It took the form of a slight erythema in the areas covered by a flannel gown. The exposed areas of skin showed no such reaction. Following the injection of anti-histamine (Benadryl 2 ml.) the affected areas returned to normal. Aortography was proceeded with and no further reaction occurred.

In the remaining cases there was no reaction whatsoever, subjective or objective to the test dose or to subsequent injection of 20 ml. of dye except in the one case where the procedure was carried out under local anaesthesia. In this case there was an intense burning feeling in the abdomen during injection but this passed off within five seconds and was attended by no other sensation or reaction.

Reference has already been made to the possibility of renal damage either from pressure or toxicity when the contents of the syringe are discharged into one renal artery. Whilst I have observed no ill effect from this accident, I attribute this to the use of sensitivity tests and the avoidance of excessive pressure. One presumably allergic reaction has recently been reported by Riches. (1955)

The patient, a man of 51, received a double injection of dye and developed an anuria lasting six days, from which, however, recovery was complete.

One fatal case has been recorded (Jasselson and Kaplan, 1954) in which death was attributed to toxicity of Neo-Iopax. The patient was markedly hypertensive with advanced cardiovascular disease and atrophic kidneys.

TRAUMA TO OTHER ORGANS.

The anatomical studies have convinced me that serious trauma to other organs should be a remote possibility. If the technique described is carefully followed no such injury should be possible. If, however, the approach to the aorta is made too lateral or too medial there is a possibility of puncturing some viscus. This has already been elaborated in the discussion of technique.

Where spinal deformity exists, it is possible to enter the spinal canal via an intervertebral foramen but under such circumstances either clear cerebro-spinal fluid will escape from the needle or there will be an absence of a free flow of blood. It is unlikely that any harm will ensue unless injection of dye is made. Under these circumstances there can be no excuse for such an accident.

Two mishaps of an unusual nature have been reported in the literature.

The first, described by Antoni and Lindgren (1949) referred to "Steno's experiment" as a complication of

aortography. This syndrome, first described in animals by Niels Steenson of Denmark in 1667, consists of motor and sensory paralysis secondary to aortic compression. In the patient described, Antoni and Lindgren attributed the paralytic manifestations to compression of the aorta from the thrust of a pillow placed under the abdomen throughout the operation. This technique, by which they hoped to fix the aorta and facilitate puncture, they have since abandoned.

The second was that published by Boyarsky (1954). The patient, a man of 63, had an abdominal aneurysm for which translumbar aortography was carried out as a diagnostic measure. Eight attempts were required before puncture was effected and in spite of two injections satisfactory pictures were not obtained. The patient developed motor and sensory paralysis below the eighth thoracic segment from which partial recovery only resulted. The theory was advanced that the spinal lesion was due to toxicity of the drug (Urokon) acting on the spinal cord via the arteria radicularis magna. It seems to me that the presence of an abdominal aneurysm, possible thrombosis of the lumbar arteries or direct injury to the cord are more convincing explanations.

PAIN FOLLOWING INJECTION

The insertion of a fairly large needle through muscle

might be expected to be followed by some degree of discomfort and muscle stiffness if not by actual pain. This, however, does not appear to be the case.

In 200 punctures carried out only 10 patients (5%) have admitted, on direct questioning, to a feeling of slight discomfort in the back, especially on movement. This discomfort did not last longer than 24 hours. Two patients, in whom dye extravasation occurred around the aorta, suffered diffuse abdominal pain associated with distension. Of the four patients found at operation to have evidence of blood extravasation none made any complaint of muscle stiffness.

The commonest complaint raised by the patients following aortography has been that of a "sore neck". Some 15% made this complaint - the condition being due to excessive rotation of the head whilst under anaesthesia, owing to the use of relaxant drugs such as Scoline.

EXTRA-AORTIC INJECTION.

This may result from improper positioning of the needle in the first instance. The needle point may have been approached too far laterally and transfixion of both walls of the aorta occurred, or the needle may not have been adjusted well into the lumen of the aorta.

Extravasation of the dye may result from

displacement of the needle during injection or by some other manipulation. This is largely a matter of technique and should be avoidable.

It is imperative that a free constant drip or stream of blood be seen coming from the needle before injection of dye is made.

Should there be any doubt about the position of the needle point, a small injection (2-3 ml.) of dye may be given by hand and the position checked by X-Ray. One equally good and quicker method is to inject a small quantity of saline and withdraw blood into the syringe. The ease with which this can be done determines the advisability of further injection of dye. In the great majority of cases there is no need to check the position as the flow of blood is quite diagnostic.

One further accident which may occur is the intramural injection of dye. This may occur in the proximal or distal wall and is more prone to occur in any degree when forcible injection is made. The injector apparatus described however, gives a better indication that such an accident is happening than other methods used such as compressed air or strong spring action, as the resistance to injection is more apparent.

The occurrence of extra-aortic extravasation does not appear to be attended by serious ill effect. There is no indication for exposure and drainage of the area.

The extravasated dye is rapidly absorbed and does not show on X-Ray films taken a short time later. Griffiths (1952) found no evidence of residual dye on X-Ray examination one hour after the extra-aortic injection of 20 ml. of Diodone. My experience suggests that the absorption of the dye is even more rapid. On one occasion 15 ml. of dye (Urokon) was extravasated round the aorta (Fig. 4). A second puncture and injection was made within ten minutes and this shows (Fig. 5) very faint evidence of what had been a dense dye concentration round the aorta.

This raises a point of practical importance. In the event of extravasation occurring, should a second injection be made through a fresh puncture or should this be postponed until another occasion? The circumstances will dictate the best policy in the individual case.

I am convinced that a second puncture and injection carries little additional risk. This has in fact been done on three occasions without any ill effect. Should the extravasated dye overlie the area to be examined, further injection should be postponed for some fifteen minutes. This of course, entails a prolongation of anaesthesia, which may be undesirable in certain circumstances. On the other hand in the majority of cases this does not carry a greater risk than that of anaesthesia at a later date.

It has been found that extravasation occurs when

puncture does not produce a good blood flow. In this event it is wiser to carry out another puncture at the same, or if desired, a different level. It cannot be too strongly emphasised that a satisfactory blood flow is essential before injection.

Extra-aortic extravasation occurred in six patients of whom two only complained of pain. In the first, the abdominal discomfort did not persist beyond 12 hours. The second patient (Case 159) received a second injection, the needle apparently becoming displaced whilst changing the tubing. Marked abdominal pain and distension were present for 24 hours but responded satisfactorily to sedation.

Intra-mural injection (Fig. 6) would appear to be a more serious accident but on the six occasions on which it has occurred the dye was even more rapidly absorbed without any apparent effect. In three of these some movement of the patient occurred just before injection due to inadequate muscle paralysis. This was considered to have caused slight dislodgement of the needle. The possibility of the later development of a dissecting aneurysm cannot be entirely excluded, but would seem remote in view of the results published by Robertson and Viner Smith (1947). They showed that even where a lesion of the intima was present a sustained pressure of 500 mm./Hg. is necessary to produce a dissecting aneurysm. Such a pressure does not occur in the human.

INJECTION INTO ONE AORTIC BRANCH.

The discharge of the whole or the major part of the contents of the syringe into one branch of the aorta may be followed by morbid changes in the organs supplied by it.

Two factors may be held responsible for such pathological changes - the effect of pressure and of toxicity. Reference has already been made to two deaths reported in the literature from mesenteric thrombosis following the injection of 20 ml. 80% Sodium Iodide directly into the superior mesenteric artery. The cause of death was attributed in each case to the toxic, necrotising effect of Sodium Iodide and not to pressure.

Four other references to the injection of large quantities of dye into one branch - the renal artery - have been published.

Melick and Vitt (1948) reported a case in which the needle was inserted into the aorta and "hit the juncture of the left renal artery." 20 ml. of 80% Sodium Iodide was introduced under pressure - they do not state how much pressure was used. The patient complained of some pain in the left loin for 48 hours and the urine contained an occasional blood cell and granular cast on microscopy. Four days later an excretion urogram and renal function both were normal.

Larsson and Palmlov (1952) quote two cases in which all the dye was introduced into the right renal artery. In

one case there was a transient fall in renal function, in the other there was no effect at all.

The dye used is not given nor is there any statement regarding whether or not pressure injection by mechanical means was used.

The third reference was that by Miller, Wylie and Hinman (1954). They quote their experiences using a pressure apparatus described as a "gas machine".

Case 1. 50 ml. of 70% Diodrast was injected into the right renal artery. The patient developed some pain and transient haematuria. Four months later the right kidney was reported to show a degree of atrophy although the calyces were normal. The published photographs of the excretion urogram, however, do not suggest to me any material atrophy of the kidney. Even accepting the opinion of these authors in view of the difficulty in reproduction of photographs one strong criticism remains. The introduction of 50 ml. of dye is excessive and there is no direct evidence that the whole effect (if any) could be attributed to pressure. The sudden flooding of the kidney with such a large quantity of medium may have produced a local irritation effect.

Case 2. 50 ml. of dye was introduced under pressure into an "aberrant" renal artery. They state that there was no untoward result.

In that case it cannot be quoted against the use of

pressure injection.

Case 3. In this case two needles were inserted and 70 ml. of dye injected. Most of the injection was made through one needle into the right renal artery whilst the remainder was injected around the right renal artery as the needle was not correctly positioned inside the aorta.

This patient developed transient hypertension and excretion urography at seven weeks showed no function for the right kidney. Six weeks later the urogram was normal.

This case hardly represents a fair commentary on pressure alone. Not only was an excessive quantity (70 ml.) injected but part of it was extravasated around the renal pedicle. Even there, however, recovery was complete.

Cases 4-7, had injections through two needles of 50, 60, 70 and 100 ml. of Diodrast. These patients all developed a degree of anuria from which however, they recovered completely. The description given of the course of events, however, is absolutely typical of acute allergic reaction. In no case was a sensitivity test carried out before the operation.

I feel strongly that the use of such quantities of dye is unnecessary and neglect of sensitivity tests in using them reprehensible. In addition, a further serious criticism is offered. The pressure attained by the "gas-air" machine was 70 lbs./sq. inch. This is equivalent to 3,800 mm./Hg.,

almost five times the pressure attained by the "injector technique" and appears to me to be beyond all reasonable practice.

The last reference was that of Riches (1955) which has already been described under allergy. Whilst a quantity of dye entered the right renal artery, no pressure apparatus was used - the injection being made by hand. The patient made a complete recovery from the anuria which resulted.

Injection into one branch occurred to a considerable degree on two occasions in this series.

The first, was a young man of 29 years who was under investigation for duplication of the left renal pelvis. The puncture was made high at the level of the 12th thoracic vertebra and the point of the needle lay opposite the origin of the coeliac axis. Injection of 16 ml. Urokon was made into that vessel. (Fig. 7) No second puncture was made in view of the unknown effect at that time of such an injection. Careful clinical observation of this patient was made over the next few weeks. No complaint whatsoever was made by the patient and no gastro-intestinal, hepatic or splenic signs or symptoms arose.

This picture, whilst affording no urological information gave excellent detail of the coeliac supply and suggests further uses for aortography in this field.

The second, was a woman of 56 years of age. She proved an interesting example of bilateral nephrolithiasis associated with a tumour of the parathyroid gland. Nephrolithotomy had already been carried out on each kidney followed by removal of the parathyroid adenoma. Following an attack of left renal colic a year later, X-Ray examination showed a stone in the lower left ureter. No function was visible on excretion urography and neither a catheter nor dye could be made to pass the stone which was impacted 7 cm. from the ureteric orifice. Aortography was performed to determine the state of the left kidney.

Aortic puncture was carried out easily, the needle being inserted just below the middle of the 1st lumbar vertebra. Injection of 18 ml. Urokon was made in 1 sec. (Fig. 8)

A satisfactory outline of the aorta and of the left renal artery and its branches has been obtained, the latter appearing to be normal. On the right side the point of the needle lies at a level corresponding to the middle of the origin of the right renal artery. An excessive quantity of dye has entered that vessel. The appearance is interesting and instructive and has not been illustrated to such a degree before. The renal artery and its main branches are densely outlined, and there is a flooding of almost the whole of the capillary bed. This dense nephrogram effect, appearing in the early film is undesirable from the diagnostic point of

view apart from the possibility of subsequent renal morbidity. The distortion of the renal outline is due to the previous operation. The area of avascularity running up from the lower pole is considered to correspond with the site of the incision in the kidney. Whilst this patient had a degree of hypertension this could not be attributed to this area of apparent ischaemia as she had a raised blood pressure before operation. The density of the nephrogram was continued into the next few films and only diminished 25 min. later.

This mishap caused apprehension regarding the possibility of renal damage and a careful clinical observation was made of this patient. The following day she admitted on questioning to some discomfort - not pain - in the right loin. There was definite tenderness in the right renal angle. This lasted a further 24 hours after which no clinical abnormality could be found. Repeated examination of the urine showed no haematuria, gross or microscopic, nor were any casts seen. Six days after aortography her output being unchanged, left ureterolithotomy (W.B.S.) was performed.

Two weeks after the operation an excretion urogram showed no impairment of renal function, the condensation and excretion of the dye being quite satisfactory and equal on both sides.

In this case no ill effect, other than transient renal tenderness, followed the injection of a considerable

quantity of dye directly into the right renal artery.

It cannot be denied that such an event remains a potential hazard. The insertion of the needle well above the renal artery origin will obviate damage to the kidney but will not preclude injection into the coeliac or mesenteric vessels. The injection of the dye at such a level or even higher will not produce such satisfactory films. It may be that puncture below the renal artery and forcible injection, as described in cases (116, 73) (Figs. 187, 124) will provide satisfactory pictures and freedom from this risk.

CONTRA-INDICATIONS.

Apart from anaesthetic considerations the only positive contra-indications to translumbar aortography consist of severe renal impairment and iodide sensitivity. The procedure is no more dangerous in tuberculosis than any other form of urography. Hypertension and arterio-sclerosis do not preclude its use if the patient is fit to undergo a short modern anaesthetic. Attention should be paid to the use of anti-coagulant therapy in vascular disease.

Whilst I have no experience of the procedure in infants, age is no bar to its use.

The youngest patient in this series was a boy of fourteen and the oldest a man of eighty-three.

FAILURE TO OBTAIN SATISFACTORY PICTURES.

1. Failure to Puncture the Aorta.

Once a proper understanding of the technique and some practice have been gained, preferably on a dead body, the chances of failing to place the needle in the aorta will diminish. Even in experienced hands, however, this event may happen. There is usually, in such cases, some associated deformity of the spine such as scoliosis, lordosis or kyphosis.

Failure to enter the aorta has occurred twice in my experience. In one case the patient had a gross deformity due to old tuberculous disease of the spine which showed well-marked Pott's deformity with kyphosis and scoliosis. This was an early case but with increasing experience it was found feasible in a similar condition (Case 106. Fig. 176) to perform a satisfactory puncture.

In the second case there was a pronounced lordosis but no lateral deviation of the spine. This patient was five months pregnant and it was felt undesirable to prolong the examination. On reflection, it is highly probable that puncture could have been effected at a higher level than the 1st lumbar body.

In the older patient with advanced arteriosclerosis there is sometimes quite marked deformity of the iliac vessels and even of the aorta. It is of importance to realise this as frequently it is just such a condition that calls for aortography. It is usual in doing this for vascular disease of the lower limbs to puncture the aorta at a level not higher than the 3rd lumbar vertebra from which level downwards the aorta frequently deviates. If difficulty in puncturing at that level is encountered, another attempt should be made higher, bearing in mind that at the 12th thoracic vertebra the vessel is more fixed and almost constant in position at the aortic opening of the diaphragm.

2. Extra-aortic injection.

Reference to this has already been made under Hazards. Satisfactory pictures will be obtained after such a mishap provided the second injection is made at a time when any dye overlying the area to be examined has been absorbed.

3. Incorrect site of puncture.

The site of election of puncture for renal arteriography is between the origin of the superior mesenteric artery above and the renal arteries below. This, however, takes no account of the variation in level of the renal arteries in the otherwise normal person, nor does it include the numerous cases of supernumary vessels in normal kidneys or the extreme variations in the blood supply to congenital renal anomalies. Nevertheless, for the usual case, it remains the preferred site. The technique originally employed of slow injection called for a reasonable degree of accuracy in placing the needle above the renal arteries but was impossible to achieve when the level was unusual. The technique described of forcible injection covers that difficulty by producing a concentrated "head" of dye which ascends the aorta.

4. Slow Injection.

This is by far the commonest cause of failure to obtain satisfactory pictures. In the early stages of the present series most of the unsatisfactory pictures were due to slow rate of injection by hand pressure. Comment has already been made regarding the necessity for ensuring a rapid concentration of dye by the use of an injector.

5. X-Ray Factors.

Satisfactory exposure factors should be confirmed by preliminary films taken before injection. Such films will also confirm the presence of twelve ribs and the exact level of the 1st lumbar vertebra, etc. Elaborate X-Ray equipment is not necessary but it is essential that there be most exact co-ordination between injection and exposure of films. A mechanical device for automatic exposure at a known time and after the injection of a known quantity is not necessary but is very helpful.

SPECIFIC CONDITIONS.

Throughout this study the opportunity has been taken to investigate a variety of conditions.

It will be appreciated that it has not been possible for a number of reasons, to examine every patient whose condition might have proved interesting or instructive.

In a number of cases where a diagnosis had already been made by other methods aortography was performed for three reasons.

First, to ascertain the angiographic appearances and relate them to the findings of other diagnostic methods.

Second, to define constant angiographic changes in specific conditions.

Third, to determine what additional information of practical value may be elicited.

In other cases it was performed to clarify equivocal findings or provide a diagnosis when other methods failed to do so.

Comment is made in the short introduction to each section regarding the angiographic appearances to be expected in the various conditions. This has been done so that the case notes and illustrations may more readily be followed and appreciated.

CONGENITAL RENAL ANOMALIES.

When one considers the development, migration and rotation of the kidneys and their complicated stages of blood supply, it is not surprising that congenital anomalies are more frequent in the genito-urinary tract than any other system of the body.

It is generally agreed that the presence of a congenital malformation of the kidney renders the organ more prone to disease. This is particularly so in the case of urinary obstruction, infection and lithiasis.

The employment of aortography in the diagnosis and management of congenital deformities of the kidneys seemed to be particularly suitable for the following reasons.

Such conditions are almost invariably associated with an abnormal blood supply. Accessory or aberrant vessels may be a factor in the causation or continuation of lesions affecting the kidney. The knowledge of the blood supply may be extremely useful in planning any surgical treatment - conservative or radical.

The diagnosis of every congenital renal anomaly is not always possible by urography alone and is never complete. Angiography, with few exceptions such as those affecting the collecting system, will furnish the diagnosis if not known and complete the investigation by demonstrating the arterial supply.

Nephrography will outline the renal parenchymal mass better than any other method. In addition the information regarding potential function is superior to that obtained by excretion urography in such conditions.

Apart from furnishing the information that an anomaly of the kidney is present, arteriography and nephrography may also be the only method of demonstrating radiologically the presence of disease in such an organ.

EMBRYOLOGY OF THE KIDNEY.

Before discussing the angiographic findings in the different congenital anomalies of the kidney, the following brief summary of the development of these organs is given to explain the extraordinary variations which may affect them.

The pronephros is the earliest form of excretory organ and consists of a series of tubules enclosing a network of capillaries at their proximal ends. Distally they empty into a common excretory duct - the primitive ureter. These tubules arise from body segments which later form the cervical

region in man.

The pronephros is an extremely transient and primitive excretory system, its whole development and degeneration being completed between the third and fourth weeks of embryonic life.

Whilst this degeneration is proceeding, a second series of tubules develops more caudally in the intermediate cell mass to form the mesonephros. Each mesonephric tubule has an expanded proximal end into which is invaginated a capillary plexus to form the earliest glomerulus. The tubules distal to this, differentiate into a secretory and collecting part, the latter emptying into the mesonephric or Wolffian duct which communicates with the cloaca. In turn the mesonephros (except a number of collecting tubules) degenerates at the third month and is replaced by the metanephros which forms the permanent kidney.

This structure, the metanephros, arises from the distal end of the nephrogenic cord which is an undifferentiated unsegmented cell mass situated caudally in the embryo. The secretory portion of this renal blastema consists of renal corpuscles and secretory tubules.

The excretory duct of this renal mass is formed from a budding from the Wolffian duct. This ureteric bud grows cranially to enter the renal blastema which forms a cap around its distal expanded end. This end becomes flattened as the

ureter grows and develops a cranial and caudal limb representing the upper and lower major calyces. These later divide to form minor calyces.

As a result of further branching, numerous tubules are formed, each capped with a cell nest from the secretory nephrogenic tissue. Eventually junction occurs between the secretory and collecting tubules.

As the ureter lengthens through growth of the body, the metanephros moves from the bony pelvis into the abdomen and comes in contact eventually with the adrenal. This upward migration of the kidney to its definitive position opposite the second and third lumbar vertebrae is accompanied or succeeded very shortly by a rotation of the long axis of the organ. Whilst in the bony pelvis the hilum faces forward but when final ascent has occurred, the hilum rotates so that it faces medially.

RENAL BLOOD SUPPLY.

The earliest blood supply to the kidney consists of the efferent branches supplying the primitive glomerulus of the pronephros. These vessels arise from the dorsal aorta but with the rapid degeneration of the pronephros they do not

persist in any form.

The mesonephric arteries take origin from the lateral splanchnic branches of the dorsal aorta. These lateral splanchnic vessels supply mesonephros, testis or ovary and suprarenal gland.

The distribution of the blood supply to the mesonephros is not regular. At the cranial end there may only be one branch to several segments whereas at the caudal end there may be as many as four arteries to each segment. In the normal course of events most of these arteries disappear along with the degeneration of the mesonephros. Those vessels originating between the sixteenth thoracic and third lumbar segments persist as phrenic, suprarenal, renal, accessory renal, internal spermatic and accessory spermatic.

The definitive blood supply of the fully developed kidney may be developed in two ways. It may simply be a survival of the mesonephric stage of development - a view first ennunciated by Broman (1906.)

Bremer (1915) however, claimed that there is no absolute specificity in the blood supply to the kidneys or intestines but that the ultimate supply was governed mainly by mechanical convenience.

Numerous sprouts are sent out by the aorta at the different stages of foetal development and these branch and intercommunicate both vertically and horizontally and from

these channels any one may become a permanent vessel. These multiple renal arteries represent the persistence of several such sprouts from the aorta. Similarly, an extra-renal branch of the iliac, inferior mesenteric or middle sacral artery represents a persistence of the more caudal elements in the anastomosis. (Anson et al. 1936)

Whatever the exact method by which the final blood supply is assured, there is no doubt it is segmental as regards its origin from the aorta and its main branches.

All observations confirm the belief that the kidney has abundant vascular connections during its entire period of development from the time it begins to ascend and rotate up to its fixed permanent position. Any disturbance of this normal migration of the kidney is likely to be attended by a disturbance in the distribution of the blood supply.

There are three ways in which the blood supply to a kidney may be abnormal. The main renal artery may have an unusual distribution, accessory vessels may be present or there may be a combination of these.

With regard to accessory vessels or branches entering the parenchyma separate from the renal sinus there are many variations.

Upper polar arteries arising from the main renal vessel usually do so at a point not far from the hilum of the kidney. Upper polar arteries may arise direct from the aorta

and enter the medial border of the kidney, usually further removed from the hilum.

Lower polar arteries from the main renal vessels are not so common.

Lower polar arteries arising direct from the aorta however, are fairly frequently found and may be of considerable surgical importance. Apart from the danger of damage to them during operations on the kidney there is a close relationship to conditions such as hydronephrosis and those requiring resection of the lower pole.

The ligation of any polar artery cannot be carried out with impunity in every case. The former practice of temporary compression of such a vessel and the assessment of ischaemia so produced is unreliable. Aortography offers a surer knowledge of the area supplied by such an artery.

There are several ways in which a main renal artery may divide at the hilum of the kidney.

The usual distribution consists of the main artery forming two divisions before the vessel reaches the hilum. One of these - the anterior or prepelvic - crosses the anterior aspect of the renal pelvis and supplies the apical, upper, middle and lower segments of the kidney. The posterior or retropelvic division passes directly to the angle of junction of the posterior aspect of the renal pelvis and the posterior lip of the hilum. It forms an arch beneath this lip before

entering the parenchyma to supply the posterior segment of the kidney.

Apart from the occurrence of a polar artery arising from the main vessel or aorta, the anomalies of renal artery pattern which are of surgical importance are as follows:-

(a) The renal artery divides into a number of prepelvic and retropelvic branches. The latter form a fan-like network over the posterior aspect of the renal pelvis.

(b) The retropelvic artery passes obliquely across the posterior aspect of the pelvis instead of forming an arch beneath the posterior lip of the hilum.

(c) The main renal artery enters the kidney by passing across the back instead of the front of the renal pelvis.

Arteriography will show the number and course of the vessels around the pelvis. It is not always possible to determine which vessels are in front and which lie behind the pelvis. This can be done if an ascending urogram is carried out at the same time. Stereoscopic films will also help to distinguish the depth of the vessels or if necessary three dimensional photographs may be made. (Figs. 234,235,236.) The latter method is rather elaborate for ordinary practical purposes and is more applicable for anatomical teaching.

CONGENITAL SOLITARY KIDNEY

Congenital absence of one kidney is by no means rare. It is said to occur once in a thousand autopsies.

Congenital solitary kidney is signified by the complete lack of development of one of the paired organs. There is entire absence of nephrogenic tissue on the one side and usually absence of the ureter and corresponding half of the trigone. The solitary kidney may be found in the normal position or in ectopic or even crossed ectopic position.

The anomaly appears to be due to an arrest in the development of the nephrogenic element of the Wolffian duct, so that the primitive nucleus of the permanent kidney fails to form.

The absence of one kidney does not incapacitate its owner for the normal physiological functions of life. The solitary kidney is, however, particularly prone to disease and its loss is fatal. The association of a pathological process such as infection or stone, leading to anuria and death, has frequently been recorded in the medical literature. Tragedies have been reported from time to time in which a solitary kidney has been removed surgically. Thomson-Walker collected eighteen cases from the literature in which a solitary kidney was surgically removed, resulting in uraemia and death within a few days.

The greatest importance, therefore, of the condition lies in its recognition. This knowledge, moreover, may be a vital factor in the management of any disease affecting it.

The diagnosis of solitary kidney is usually made by cystoscopy, excretion and retrograde urography.

In the majority of cases such methods prove adequate, both for diagnosis and assessment of function. Where the results from such examinations are not satisfactory, however, renal arteriography will prove helpful and even more informative.

The presence of one ureteric opening in the bladder seen on cystoscopy usually suggests solitary kidney, especially where there is a deficiency of the trigone on the other side. Nevertheless, it is possible for the ureters of two kidneys to fuse before entering the bladder as one opening. Should excretion and retrograde urography be unsatisfactory or the cystoscopic findings in any way be doubtful the diagnosis may remain equivocal.

Aortography performed in such cases of solitary kidney will show a complete absence of a renal artery on the affected side. Particular care should be taken to trace the outline of the wall of the aorta on that side. Where the entire kidney is absent the renal artery is also absent and the aortic line is regular and unbroken. In cases of auto-nephrectomy or hypoplasia the stump of origin of the artery

will be seen or at least there will be a slight notch in the aortic wall at that level. There is a complete absence of nephrogram effect.

Apart from affording such diagnostic proof of the congenital absence of one kidney, arteriography determines more fully the condition of the solitary kidney. Where surgical treatment of this kidney is required it must of necessity be conservative and the information provided by angiography should simplify and clarify the contemplated procedure.

One other consideration may be worthy of mention. Instrumental examination is not entirely free from sequelae. Should infection be introduced into a solitary kidney the management of the patient may be gravely altered. The use of arteriography may well be justified on these grounds alone.

In this series six such cases have been examined by aortography.

Case (1) E.C. Female aged 32.

History

This woman attended the Surgical Outpatient Department in March, 1953, complaining of pain in the right loin. The pain, which had been acute at times, had been present intermittently for four months. Clinical examination

revealed no abnormality and the pain was considered to be of renal origin. Excretion urography was carried out and showed the right kidney to be normal in respect of function and calyceal outline. No excretion of dye was seen on the left side. Numerous opacities were present in the left renal area and it was thought that these might be due to calcification and and that autonephrectomy of a left tuberculous kidney had occurred. She was sent to the Urological Department for further examination.

Urological Investigation.

No clinical abnormality was found and the urine contained no abnormal constituents.

Cystoscopic examination on 3.4.53 revealed congestion of the mucosa in the region of the normal site of the left ureteric orifice. The latter could not positively be identified and so retrograde urography was not possible. It could not be stated to what degree, if any, defective trigone was present.

Arteriography was performed on 8.5.53, after admission to hospital and is illustrated in Fig. (9). This shows a right kidney outline, normal in size, shape and position. The renal artery to it is large and has a normal site of origin, course and distribution.

There is complete absence of any arterial segment on the left side. The aortic wall is smooth and unbroken.

The small vessel seen running diagonally up to the left edge of the second lumbar vertebral body is a typical lumbar artery.

The nephrogram phase showed as would be expected complete absence of nephrogenic tissue on the left side, whilst the right was normal in all respects.

In this case the usual examination methods did not prove conclusive whereas arteriography provided a definite diagnosis of congenital solitary right kidney.

No operative treatment was indicated and the right-sided pain gradually subsided. After treatment with a sedative alkaline mixture she was discharged home and has remained well since.

This was the first occasion on which the injector was used and was the first really satisfactory picture to be obtained.

Case (2) M.C. Female aged 23

History

This young woman was first seen as an outpatient on 29.4.55. She stated that for the last three years she had suffered from "leakage after passing urine". This incontinence was variable and occurred also at night. She had no other complaint.

She had been investigated at another hospital a year previously and was told that "the left kidney was lazy and

not working well".

Urological Investigation

On clinical examination the lower pole of the right kidney was easily palpable but otherwise no abnormality was found. The urine examination was normal.

Cystoscopy on 29.4.55 showed a normal bladder capacity and mucosal appearance.

The left ureteric orifice was not identified.

Excretion urography on 4.5.55 showed a normal right kidney but no evidence of dye on the left side.

On 9.5.55 a further examination of the bladder was made but retrograde urography could not be done as the left orifice again was not identified. Indigo-carmine was injected intravenously and appeared in 3 min. at the right orifice but failed to demonstrate any left opening. The report of this examination stated that the presence of a left orifice "must be regarded as equivocal."

It was unlikely that her incontinence was due to an ectopic ureteric opening in view of the absence of such on clinical examination of the genitalia and the short history of the complaint. As the conclusions following chromo-cystoscopy were not absolutely definite it was decided to employ aortography.

On 15.8.55 after admission to hospital this was carried out. The result of this examination was not

satisfactory due to a technical radiological fault - the first cassette being moved too soon. The examination was repeated four days later.

The arteriogram (Fig. 10) clearly shows a double blood supply to the right kidney. The main vessel, which is the upper one, arises at the level of the lower border of L.1, whilst the accessory artery arises one vertebral body lower, and supplies the lower third of the kidney.

There is complete absence of a left renal artery, the wall of the aorta in that region being quite clear and continuous.

The nephrogram (Fig. 11) shows a good large right renal shadow and complete absence of renal tissue on the left side.

The diagnosis of solitary kidney was thus complete and definite.

No operative treatment was necessary and the patient responded to Pro-Banthine therapy.

Case (3) J.D. Female aged 20

History

This girl was admitted to a medical unit in March 1955, complaining of right-sided pain. This had been present constantly for the previous ten days and was associated with frequency, dysuria and slight terminal haematuria. She was

referred for examination of the urinary tract.

Urological Investigation.

Clinical examination on 27.4.55 elicited tenderness in the right loin. No renal enlargement was palpable.

Excretion urography was performed on that date but showed no obvious dye excretion on either side.

The urine was found to be heavily infected with B. Coli.

Further investigation was refused by the patient, who was of a low mentality and she left hospital on 2.5.55 with considerable improvement in her symptoms and general condition.

Following a recurrence of pain she was re-admitted on 12.5.55 and excretion urography was repeated. On this occasion the upper calyces of the right kidney were visualised and seen to be somewhat dilated. No dye could be seen on the left side.

The urine was still infected with B. Coli and this was treated with Chloromycetin.

On 24.5.55 cystoscopy was performed under general anaesthesia as she would not tolerate the examination otherwise. The left ureteric orifice was not seen and retrograde catheterisation could not therefore be done.

Some doubt remained whether this was in fact a solitary kidney as the bladder mucosa was somewhat infected

and oedematous near the normal site of a left orifice.

Aortography was performed on 27.5.55 in an attempt to clarify the position.

The preliminary puncture did not provide as good a blood flow as usual but was thought to be adequate. Following injection, which was not as fluent as usual, extravasation was suspected and confirmed on the X-Ray films. A second puncture, 10 min. after the first one, was made and a satisfactory picture obtained.

Reference has already been made to this case when extravasation was discussed. (Figs. 4 and 5.)

The aortogram shows no evidence of vascularity on the left side, either in the arteriogram or nephrogram phase.

It was now clear that the condition was one of congenital solitary right kidney with a normal blood supply.

Further treatment was directed to the elimination of the urinary infection.

The fourth patient, (Case 113) was a woman aged 59, on whom an uretero-colic anastomosis had been performed on the right side ten years previously. (A.J.)

Investigation, including cystoscopy, urography and operation, proved that she had a congenital solitary right kidney, the condition for which transplantation was performed being a vesico-vaginal fistula.

Aortography was done in this case to assess function and will be described in more detail under Uretero-colic anastomosis.

Reference to the illustration, however, confirms the arteriographic appearances in such cases, namely a clear, unbroken, regular aortic wall on the agenesic side. (Fig. 184)

The next patient differed from the previous ones in that two ureteric openings were present in the bladder. This finding is extremely uncommon in congenital solitary kidney.

Case (4) T.M. Male aged 41.

History

This man was admitted to a medical unit in July, 1955, with a vague history of recurrent attacks of vomiting. He was somewhat mentally retarded and was unable to give a coherent account of his complaints. He appeared to have some abdominal discomfort mainly in the epigastrium. He was reputed to have lost weight during the previous two years.

A full medical examination had not revealed any significant abnormality. The urine contained a trace of albumen and a few pus cells.

He was referred for full investigation of the urinary tract.

Urological Investigation.

Clinical examination on 6.8.55 was essentially normal

except that both testes were small.

Cystoscopy yielded a clear urine and the bladder appearances were normal apart from the small size of both ureteric orifices which, however, were in the normal position.

Excretion urography on 8.8.55 was unsatisfactory as a faint dye shadow was present only on the left side.

In view of this ascending urography was attempted two days later. The catheter failed to pass up the right ureter and no picture was obtained on that side. The left pyelogram showed clubbing of all the calyces.

Aortography was carried out on 15.8.55. The arteriogram (Fig. 12) shows a reasonably good blood supply to the left kidney although the cortical branching is rather poor. There is a complete absence of any vascularity on the right side. The aortic wall is quite smooth and regular.

The nephrogram showed that the left kidney had retained to some degree its foetal shape of polar approximation. No other parenchymal shadow was seen.

In view of the presence of a right ureteric opening ascending urography was again performed on 19.8.55. On this occasion a catheter was passed 15 cm. up the right ureter and completely up the left.

The retrograde film shows (Fig. 13) no dye beyond the iliac crest on the right side, the portion of ureter outlined being dilated. The left pyelogram shows clubbing

of the calyces and dilatation of the pelvic ureter.

These results proved somewhat puzzling.

On the one hand the angiographic findings strongly suggested complete absence of renal tissue on the right side. The urograms, however, showed that at least a pelvic ureter was present on that side and there remained the possibility of a non-functioning obstructed kidney.

As these were the only abnormal results of many examinations it was decided to explore the right side.

Operation.

The right renal space was opened on 23.8.55, (W.B.S.) through the usual loin incision. An excellent exposure was obtained and a careful search failed to show the presence of any renal or adrenal tissue. Detailed dissection and examination of the vena cava and aorta did not show any vessels on the right side which could be related to renal tissue. Mobilisation was not carried below the pelvic brim as this would have entailed an extension of the incision which was not considered justifiable. Identification of the pelvic ureter was not made but there was certainly no evidence of a ureter above the pelvic brim.

In view of the complete absence of renal tissue this case must be considered as one of congenital absence rather than renal aplasia.

The aortographic appearances were correct and more

accurate than those suggested by the urograms.

The last patient resembled the previous one in that two ureteric openings were present although the length of that on the affected side could not be determined.

Case (5) J.G. Male aged 46.

History

This man complained of pain in the right loin which was present intermittently over the previous two years. He was sent to the General Surgical Outpatient Department on 27.8.55, where no clinical abnormality was found. Although he had no associated urinary symptoms it was considered that the pain was of renal origin.

Excretion urography was performed which showed no evidence of dye on the left side, the right kidney being apparently normal. He was referred to the Urological Department.

Urological Investigation.

No clinical abnormality was found other than slight tenderness in the right loin. The lower pole of the right kidney was easily palpable.

There were no abnormal urinary constituents.

Excretion urography on 2.9.55 confirmed the previous findings, the function and outline of the right kidney being normal. No dye was present anywhere on the left side.

Cystoscopy on 7.9.55 was quite normal, both ureteric openings being of normal size, shape and position. Retrograde catheterisation of the left ureter failed as even the smallest catheter could not be made to ascend beyond the orifice.

He was admitted to hospital and aortography carried out on 19.9.55.

The arteriogram (Fig. 14) shows a good normal blood supply to the right kidney. On the left side no renal vascularity can be seen and the aortic wall is regular.

The only nephrogram effect was that of the normal right kidney.

These appearances were considered to be sufficient for the diagnosis of congenital solitary kidney to be made.

No specific treatment was necessary in this case as the right-sided pain subsided and the patient has remained free from discomfort since.

RENAL ECTOPIA.

Ectopia of the kidney is due to interference with the migration of the renal anlage during foetal development. The range of displacement of the ectopic kidney is considerable and it may be found anywhere between its normal position and the base of the bladder.

The blood vessels supplying the ectopic kidney are always anomalous. These arteries may arise from the aorta, iliac, middle sacral or inferior mesenteric vessels. The displacement of the kidney to one side does not necessarily entail the blood supply arising from that same side of the aorta - it may arise from the other side and run across.

An ectopic kidney seldom gives rise to symptoms unless it is diseased. Not infrequently, however, such kidneys not only drain defectively but have a poor nourishment due to the inadequacy of the anomalous vessels which provide their blood supply.

Several types of ectopia renalis have been investigated in the present series.

Simple Unilateral Ectopia.

This condition which is reported to occur with a frequency of 1/1000 and is not related to sex or side, consists of the arrest of one kidney at a lower level on that side than

its normal location. Such cases may conveniently be divided into abdominal, iliac and pelvic and examples of two such types are afforded by the following.

Abdominal Ectopia.

Case (6) J.B. Female aged 38.

History

This patient had a colectomy performed for ulcerative colitis on 8.9.54. Two months later she was found to have a palpable mass low in the right side of the abdomen. This mass lay below the ileostomy opening. Whilst it did not appear to be causing any symptoms referable to its presence it was thought advisable to investigate the nature of the swelling and she was referred for detailed examination as a suspected ectopic kidney.

Urological Investigation.

An excretion urogram on 17.11.54 showed the left kidney to be normal in size, shape, position and function.

No evidence of dye was seen in the right renal area and no renal parenchymal outline could be made out anywhere on that side.

Aortography was performed on 19.11.54 with the following result.

The arteriogram (Fig. 15) shows the left kidney to

be normal in respect of blood supply and distribution. On the right side the kidney lies low and has a double blood supply. The upper main artery arises from the aorta at the level of the upper border of the 2nd lumbar vertebra. A major branch is given off from the renal artery a short distance from the aorta and runs to the kidney parallel to the main stem. An accessory vessel supplies the lower pole running transversely to it from the aorta at the level of the lower border of the 3rd lumbar vertebral body.

The blood supply to the kidney is good and as would be expected, the nephrogram effect is quite dense, denoting equally good vascularity and excretory function within the kidney. The latter is shown to lie between the 2nd and 4th lumbar bodies and retains to some degree its foetal shape in that the poles approximate each other. (Fig. 16)

In view of the absence of symptoms and these findings, no operative treatment was advised.

The performance of aortography for diagnosis of this case was vindicated by these findings. It may be said that retrograde urography would have proved as valuable. It is not disputed that, provided catheterisation of the ureter was effective and a good picture obtained, the diagnosis could have been made. Nevertheless, the outline, size and position of the renal mass could not have been determined, nor could any

knowledge have been gained of the blood supply and functioning parenchyma.

One further important point of information obtained is that a differentiation may be made between congenital ectopia and ptosis. Further reference to this will be made when the latter condition is considered.

Unilateral Pelvic Ectopia.

In this condition, the displacement of the kidney is extreme. It has failed completely to ascend from its rudimentary position in the pelvis. The kidney lies in the true pelvis, either over the promontory of the sacrum, in the concavity of the sacrum or on the floor of the pelvis.

The renal mass is usually flattened and disc-like. The hilum is more often than not directed forwards and there is frequently absence of a proper renal pelvis, the calyces uniting to end directly in the ureter. The greatest variation, however, lies in the blood supply.

The arteries and veins have their origin and termination respectively in immediately adjacent large vessels.

The importance of the diagnosis of pelvic kidney is easily recognised when, for clinical purposes, they are divided as follows:-

(1) Those presenting symptoms referable to the urinary tract.

(2) Those simulating gynaecological or other abdominal conditions.

(3) Those presenting symptoms during pregnancy or dystocia.

In a number of cases the diagnosis is made quite fortuitously in the course of routine investigation in which no symptoms are referable to the pelvic kidney.

The next case illustrates this type.

Case (7) J.I. Male aged 54.

History

This man was seen as an outpatient on 16.2.54, complaining of recurrent attacks of pain in the right iliac fossa for the past year. During these attacks of pain there was associated frequency of micturition and dysuria.

Urological Investigation.

On clinical examination there did not appear to be any appendicular lesion present. There was a mass palpable in the hypochondrium. The mass was firm, smooth and lay more to the left of the midline. It was obviously not a distended bladder, and was slightly tender on deep palpation.

Excretion urography was carried out on 17.2.54 and showed the right kidney to be normal in size, shape and position. The function was good and the anatomical pattern of the calyces and pelvis normal. There was, however, a small shadow present in the region of the lower end of the right ureter. This was

considered to be a stone which was responsible for the pain and tenderness in the right side.

No dye was present in the left renal area but could be seen faintly within the bony pelvis.

Ascending urography on 19.2.54 confirmed that the right kidney was normal in all respects and that the above shadow was in fact a stone. On the left side the presence of an ectopic kidney was confirmed but only the calyces were demonstrated and the size and shape of the kidney remained indeterminate.

Low aortography was performed on 22.2.54. In this case the needle was inserted at the level of the 3rd lumbar vertebra. The arteriogram shows (Fig. 17) that the left kidney is supplied by one main vessel arising from the left anterior aspect of the aorta just above its bifurcation at the level of the 4th lumbar vertebra. It will be seen that a short distance from the aorta the renal artery gives off a main branch to the kidney.

The nephrogram (Fig. 18) shows a dense parenchymal outline of the kidney tilted somewhat obliquely to the left.

In this case no operative treatment was performed as the anomaly was not giving rise to symptoms and attention was directed to the right ureteric calculus.

If surgery had been carried out, the aortographic findings would have assumed greater significance.

In planning the approach to the kidney, ligation of the pedicle should be performed close to the aortic bifurcation at the point proximal to the origin of the first branch. In so doing, a relatively bloodless operation could be achieved. Without the knowledge of the blood supply shown on the arteriogram, a somewhat tedious dissection may be required before a true appreciation of the vascular distribution is achieved.

In addition to this, the exact size and configuration of the kidney, defined so clearly by nephrography, is helpful in planning the surgical approach in unusual or difficult sites.

Bilateral Pelvic Ectopia.

This differs in no way from the previous condition except in so far as both kidneys are involved.

The next patient is an illustration of double pelvic kidneys.

Case (8) A.M. Male aged 23

History

This young man attended the Surgical Outpatient Department on 23.7.54, complaining of pain in the right iliac fossa. He stated that he required to pass urine more frequently since the pain started, six weeks previously. There was also associated pain and discomfort on micturition.

He had not seen any blood in the urine.

In the course of investigation, an excretion urogram was carried out, which showed absence of the kidneys in the loins and evidence that both organs lay within the bony pelvis.

He was referred to the Urological Departement for further investigation as it was thought that the position of the kidneys might be responsible for his complaint.

Urological Investigation.

On clinical examination, the kidneys were not palpable above the symphysis pubis nor could any abnormality be detected on bimanual examination.

Cystoscopy carried out on 10.8.54 showed the bladder to be quite normal with both ureteric orifices present. They were normal in size, shape and position and a clear efflux noted to be coming from each one.

Ascending pyelography on that date, showed both kidneys to overlie the sacrum. There was slight fullness of the right renal pelvis.

In order to determine the renal outline and blood supply, aortography was performed on 20.8.54, using a low puncture at the level of the 3rd lumbar body.

As Fig. (19) shows, the aorta bifurcates at the high level of the 3rd lumbar vertebra. The renal arteries arise from the aorta just about the bifurcation, although from the anterior aspect of the aorta and maintain their respective

positions of right and left. The right renal artery deviates slightly to the lateral aspect of the right common iliac vessel. The first major division occurs just before the branches cross that vessel to descend straight down to the right kidney. The left renal artery divides somewhat higher over the centre of the 4th lumbar vertebra and descends vertically to the left kidney.

The nephrogram shows (Fig. 20) fairly even condensation of the dye with apparent fusion of the kidneys.

No surgical lesion of significance was present in the kidneys to account for the recent onset of pain apart from the possibility of infection of one segment.

The following day the pain became more severe and at first consideration was given to the possibility that the pain was renal in origin and had been exacerbated by the examination. There was no evidence whatsoever of toxicity and no abnormality could be found in several specimens of urine.

The symptoms, however, gradually assumed the typical characteristics of acute appendicitis and this was confirmed at appendicectomy that evening.

In this case, the anomaly was not responsible for any symptoms but the value of aortography is clearly shown in such conditions.

In addition to the demonstration of the origin,

course and distribution of the vessels, the degree of functioning parenchyma and the outline of the renal mass, it shows the presence or absence of fusion of renal tissue. This is of considerable value when operative treatment of one kidney is necessary.

INCOMPLETE ROTATION AND MALROTATION.

In early embryonic life, the hilum of the kidney faces the ventral aspect of the foetus. In the second month when ascent of the kidney takes place there is a concomitant rotation of the organ so that when it reaches the normal position in the loin the hilum faces medially.

A common abnormality is failure to complete the full medial rotation and this faulty rotation, either incomplete or excessive, is a frequent accompaniment of other abnormalities such as ectopia or fusion of the kidney.

Two cases have been investigated which illustrate this failure to achieve the normal rotation.

Unilateral Malrotation.

Case (9) J.L. Female aged 41.

History

This woman had suffered intermittent attacks of pain in the left side for two years. The pain was felt also in the left iliac fossa and was sometimes accompanied by urgency and frequency of micturition.

She was sent to a general surgical outpatient department where in the course of examination an excretion - urogram showed that the left kidney was abnormal.

She was referred for urological examination on 17.8.55.

Urological Investigation.

The excretion urogram showed the left kidney to be malrotated and low in position. The pelvis and calyces were not completely outlined but appeared to be dilated.

The right kidney was normal in all respects.

Cystoscopy on 17.8.55 was normal - the urine being clear and free from infection.

Left ascending pyelography on 17.8.55 shows (Fig.21) a low-lying kidney between the 3rd and 5th lumbar bodies with considerable dilatation of the pelvis and calyces. The former appears to face anteriorly whilst one of the latter faces medially and the remainder anteriorly.

In view of these appearances it was considered that

the dilated anomalous kidney was responsible for her symptoms and might require removal.

Aortography was carried out on 26.8.55.

The arteriogram (Fig. 22) shows a normal blood supply to the right kidney. There is a double blood supply on the left side. The upper major vessel arises at the middle of the 2nd lumbar body and supplies the upper part of the kidney. This vessel is somewhat overlaid by the branches from the superior mesenteric which, however, are readily distinguished. The lower vessel arises at the level of the upper border of the 4th body and runs upwards before branching and descending to supply the lower pole.

The nephrogram (Fig. 23) shows that the left kidney has preserved the normal adult bean shape. The position of the convex border and hilum is reversed so that the latter faces outwards.

This should be regarded as a case of malrotation rather than incomplete or excessive rotation.

No surgical treatment was carried out on this patient as she was unwilling to undergo operation.

Had operation been undertaken the knowledge of the double blood supply and the peculiar malrotation shown by the nephrogram would have proved useful.

The next patient illustrates the bilateral type of incomplete rotation.

Bilateral Incomplete Rotation.

Case (10) A.M. Male aged 24

History

This man first complained of some discomfort in the left loin in February, 1954. He was examined as an outpatient with the following results.

No clinical abnormality was found and the urine contained no unusual constituents.

Excretion urography on 9.2.54 showed no opaque calculus. The left renal pelvis was elongated and the lower group of calyces faced medially. On the right side the pelvis and calyces faced forwards.

Ascending urography performed a week later confirmed these appearances and a diagnosis of horseshoe kidney was made on these findings.

The cystoscopic appearances were normal.

No operative treatment was advised and he remained well until December, 1954 when he had an attack of severe pain in the left loin. He returned for further examination.

Urological Investigation.

Excretion urography on 16.12.54 showed a calculus in the left renal pelvis which was slightly dilated; apart from this the appearances were as seen in February. The diagnosis was made of a stone in the pelvis of the left half of a

horseshoe kidney.

He was admitted to hospital and further X-Ray on 21.1.55 confirmed the presence of stone.

No clinical abnormality was found other than slight tenderness in the left hypochondrium.

The urine analysis was normal.

It was decided to use aortography to complete the diagnosis and confirm the congenital anomaly.

Aortography was carried out on 29.1.55.

The arteriogram (Fig. 24) shows considerable abnormality in the renal blood supply. On the right side four distinct renal arteries arise from the aorta between the upper borders of the 1st and 4th lumbar vertebral bodies. On the left side three renal arteries arise within the same distance.

The nephrogram (Fig. 25) however, shows clearly that the kidneys are not joined together but are quite separate at the lower poles.

The nephrogenic effect will only be apparent where there is vascular functioning tissue. It may be said that it is possible for the kidneys to be joined together by a non-functioning fibrous tissue bridge. Whilst neither I nor any of my urological colleagues have seen such a fibrous tissue isthmus in horseshoe kidney it has been described in the literature. In this case, however, the parenchymal outline of each lower pole is so distinct, smooth and even that it was

considered highly unlikely that any such union could exist.

Operation

At operation on 1.2.55 (W.B.S.) the stone was removed. The angiographic findings were confirmed in all respects, there being no fusion at the lower poles.

One other important pre-operative point was elicited.

In cases such as incomplete rotation or fully developed horseshoe kidney, there may be some deficiency in drainage of the pelvis due to the course of the ureter. Any surgical procedure aimed at elevation and fixation of the kidney by some form of nephropexy will depend on the degree of mobility of the segment. This is closely related to the length and position of the blood supply.

The arteriogram in this case strongly suggested that neither kidney could be elevated appreciably owing to the short vessels supplying the lower poles.

This also was confirmed at operation but as the course of the ureter was normal, nephropexy was not required.

RENAL FUSION.

Another common form of congenital renal anomaly consists of the fusion of nephrogenic tissue. This may take the form of median fusion. Where one-half of the mass extends across the midline of the body, the condition is referred to as horseshoe kidney.

Where such fusion confines the mass to one side of the midline, the condition is termed crossed renal ectopia. In each case the ureters do not unite but follow a separate course ending on opposite sides of the bladder.

A third type is that of double kidney, in which the ureter may show complete or incomplete duplication but enters the same side of the bladder.

These anomalies are quite distinct.

HORSESHOE KIDNEY.

Reports of clinical records show that horseshoe kidney is not a rarity and it is found as frequently as 1/1000 autopsies.

The halves of a horseshoe kidney may be more or less symmetrical. In that case they are of equal size and lie at the same level. In at least 90% of the reported cases, the

junction between the halves has been inferior.

More commonly there is an asymmetrical fusion. In this case the halves lie at different levels and may be equal or of different size. Various descriptions have been applied such as L shaped, cake shaped or sigmoid, but they all represent types of the one condition, namely horseshoe kidney.

A consideration of the anatomical relationship of horseshoe kidney is important not only for recognition of the condition but also for recognition of lesions which may arise in such an anomaly.

In the case of normal kidneys the long axes lie obliquely and are directed downwards and outwards. The pelves and calyces are arranged in the sagittal plane with the latter pointing laterally.

In horseshoe kidney usually the reverse obtains.

The axes of the kidneys are directed obliquely downwards and inwards. There is considerable variation in the relationship between renal tissue and the spine. As a rule both halves lie close to the spine and one may even overlap it. Nevertheless, the variation is so great that one half may lie in the normal position or both halves be as far from the spine as in the normal patient.

The pyramids are arranged on a frontal instead of a sagittal plane and so some of the calyces are directed medially. This is of diagnostic urographic importance.

As a result of faulty rotation many of the calyces point ventrally and the pelvis usually lies on the anterior aspect.

The isthmus connecting the two halves usually connects the lower poles. Its width is variable but in the great majority of cases it contains parenchymal tissue and may even contain calyces. A purely fibrous union is most uncommon and the average width of the isthmus is 3 cm.

In almost every case the isthmus lies in front of the aorta but it has been found on rare occasions to lie behind the aorta and vena cava.

The level at which a horseshoe kidney lies is somewhat variable and this is hardly surprising when the considerable variation in shape is taken into account. The majority lie between the 3rd and 5th lumbar vertebrae. The reason for this may well be the level of the inferior mesenteric artery which will act as a restraint to the further ascent of the organ.

The few cases in which a horseshoe kidney is reported to have taken up the normal position may well have been retroaortic and retrocaval although no opportunity has arisen to confirm this personally.

Not uncommonly, the fused mass may lie in the bony pelvis, constituting the cake kidney.

The position of the ureter too, is of importance both from a diagnostic and pathological viewpoint.

As a rule, the ureters cross in front of the isthmus and deviate from the midline to a greater degree than that seen in the normal. In addition, the ureter not infrequently arises from a higher point of the renal pelvis than the normal dependent portion.

The blood supply is quite irregular. Multiple arteries for each half and for the isthmus are a common occurrence and these accessory arteries occur more frequently in horseshoe kidney than in any other congenital renal anomaly. On the other hand, the blood supply to the whole renal mass may derive from one vessel. (Doss, 1946.)

Under such circumstances it would be catastrophic to divide the isthmus. It therefore seems only reasonable to determine the state of the blood supply when operation is contemplated in horseshoe kidney.

The occurrence of accessory vessels is important in two ways.

First, these vessels, particularly those supplying the lower portions of each half, are usually short arteries. This explains the finding that in spite of the absence of perinephric fat such kidneys are well fixed.

As already mentioned any operative treatment such as division of the isthmus and the mobilisation and fixation at a higher level of one segment by nephropexy depends on the length of these arteries if present.

Second, the presence of accessory vessels may contribute to obstructive lesions of the pelvis or ureter.

In the present series three patients with this abnormality have been investigated by arteriography.

The first two are examples of the symmetrical type whilst the third shows the asymmetrical type of renal fusion.

Case (11) J.D. Female aged 39

History

This patient was referred from the surgical outpatient department on 5.10.54 with the following history. She had suffered attacks of pain in the left side for the previous three years. The pain was intermittent and acute and sometimes radiated to the left groin. There was associated frequency of micturition. In addition to these symptoms she had found it increasingly difficult to straighten her back after stooping - the act being associated with abdominal pain.

She had undergone appendicectomy in June, 1954.

In view of the persistence of the above symptoms excretion urography was done and showed the typical appearance of horseshoe kidney.

She was sent for further urological examination and treatment.

Urological Investigation

No clinical abnormality was found. The pain on straightening her back after stooping (Rovsing's sign) was confirmed.

Excretion urography was not repeated, the previous examination on 26.9.54 being satisfactory for diagnostic purposes.

As she would not tolerate instrumental examination without general anaesthesia, it was decided to employ aortography rather than retrograde urography. It was considered that this would afford greater information.

Aortography was done on 26.11.54.

The arteriogram (Fig. 26) shows that there is on each side a fairly normal renal artery arising at the lower border of the 1st lumbar body. That on the right side is slightly larger. These vessels supply the upper two-thirds of each kidney.

The vascular pattern within the area of kidney so supplied is quite normal. There are in addition two accessory vessels, symmetrical and of equal size, supplying the lower third or pole of each half and the isthmus. These vessels arise from the medial aspect of the aorta at its bifurcation at the 4th lumbar vertebra and run behind the common iliac vessels to supply renal tissue. They are of fairly large size and have a good normal end distribution.

The nephrogram (Fig. 27) shows that the renal mass is

almost symmetrical. The left half is slightly larger and higher. The medial obliquity so usual in the excretion urograms is shown to start about the middle of each renal mass. Above this the kidneys have assumed an almost normal position and axis. The isthmus is broad and extends over the 3rd and 4th lumbar bodies.

In view of the classical pressure symptoms occurring in this patient, operative treatment was carried out.

Operation.

At operation on 2.12.54 (A.J.) the angiographic appearances were confirmed, the isthmus being considerable and containing obvious normal renal tissue. Simple division of the isthmus was performed through a lumbar incision as this is frequently sufficient to relieve such symptoms. Nephropexy was not considered necessary, but in any case could not have been performed without danger to the lower polar vessels.

The result of this operation was entirely satisfactory.

In this case the value of aortography was threefold.

First, it defined the exact blood supply and demonstrated the presence of more than one vessel to the mass.

Second, it showed the degree and amount of functioning tissue.

Third, the whole mass, including isthmus, was defined and its relation to other structures demonstrated.

Case (12) W.C. Male aged 51

History

This man was sent to the Urological Department on 3.12.54, having had an attack of left-sided colic ten days previously. He had suffered intermittent discomfort in the left loin for almost a year.

Urological Investigation

No clinical abnormality was made out.

Excretion urography on 3.12.54 was not very satisfactory as the dye concentration was poor on each side. It did, however, suggest incomplete rotation of the left renal pelvis and the possibility of horseshoe kidney.

Left ascending pyelography on 14.12.54 clearly showed an elongated incompletely rotated left kidney.

It was decided to complete the investigation by angiography and he was admitted to hospital on 13.4.55. This was done on the following day.

The arteriogram showed two large but apparently normal renal arteries arising at the level of the lower border of the 1st lumbar vertebra. They run obliquely down to give an extensive supply to the renal mass, as shown on the nephrogram. (Fig. 28) This case is of the symmetrical type as each half is approximately equal in size and position.

No operative treatment was advised as the symptoms subsided following a generous fluid intake.

The third case in the series was of the asymmetrical type.

Case (13) E.R. Female aged 39

History

This patient had been admitted to a Medical Unit in August, 1954. She complained of intermittent pain in the abdomen, which was first felt two years previously. This pain was usually present in the middle of the abdomen but occasionally extended into both groins. One week before admission she had felt this abdominal pain and noticed for the first time a tender swelling near the umbilicus.

Amongst other investigations, excretion urography was done on 18.9.54 and showed that the middle and lower calyces of the left kidney pointed medially.

The right renal outline was indefinite but appeared to lie over the spinal column.

She was referred for further examination of the urinary tract.

Urological Investigation

On clinical examination a slightly tender solid mass was felt in the abdomen. It extended from below the umbilicus to the right of the midline upwards to the left hypochondrium. The margins were indefinite.

The urographic appearances were indicative of horseshoe kidney but as full detail of the calyces, especially

on the right side, was lacking, an attempt was made to obtain retrograde films.

This was not possible as the patient was unable to tolerate cystoscopy.

As a general anaesthetic was necessary for this it was decided to use angiography rather than repeat the attempt at retrograde catheterisation.

Aortography on 24.9.54 showed the following vascular supply.

The arteriogram (Fig. 29) shows that on the right side there is one renal artery arising at the upper border of the 1st lumbar vertebra. After reaching the lateral border of that vertebral body it descends vertically to supply the right side of the mass as far as the 3rd lumbar vertebra. On the left side the mass is larger and there are two distinct arteries. The larger upper vessel arises at the same level and has the appearance of the artery seen in normal kidneys. The lower vessel arises at the lower border of the 2nd body and shortly after its origin bifurcates into two main branches. The upper one supplies the remainder of the left kidney whilst the lower supplies that part of the right kidney which overlies the left.

This is demonstrated on the nephrogram, (Fig. 30) which shows that the joined renal mass consists of an almost normal left kidney as regards size, shape and position. The

right kidney, however, tends to lie almost transversely across the abdomen and extends to overlie the medial part of the lower pole of the left kidney.

The blood supply is of interest in this case. The isthmus usually is supplied by a separate vessel or vessels arising directly from the aorta or other main vessel near the level at which it lies. In this patient the vascular supply consisted of a branch from a vessel arising fairly high in the abdomen.

No operative treatment was carried out on this patient as her symptoms were not marked and she was a definite neurasthenic type.

These three examples clearly show the astonishing variation in the blood supply to horseshoe kidneys.

They suggest that renal angiography contributes information of practical diagnostic and surgical value. It is felt that there is every justification for this procedure before operation in such cases.

CROSSED RENAL ECTOPIA.

Under normal developmental conditions the renal blastema of each side migrates upwards to the final position in the respective lumbar regions. An arrest of such migration results, as already mentioned, in simple ectopia.

If, however, for some reason as yet not fully known, the nephrogenic mass, instead of moving upwards on its own side, is deviated to the opposite side of the body, the condition of crossed ectopia exists. Thus, the result of such developmental error is the presence of both kidneys on the same side of the body. The kidneys may remain separate or be fused. The latter is much more common but in either event the ureters do not join but follow a separate course to end on opposite sides of the bladder.

The term "unilateral fused kidney" is sometimes mistakenly used to describe such cases where fusion is present. If used at all it should only refer to double kidney in which the ureter or ureters draining the fused mass enter the bladder on the same side.

The ureter of the lower ectopic kidney is, as a rule, the one which crosses the midline to regain its proper position.

With regard to the relation of the two kidneys to each other there are as many variations as there are possible the degree of rotation of the component halves.

Thus, the kidneys may be joined end to end, at an acute angle to each other, overlapping each other, or at right angles. The direction in which the hilum of each faces may be as follows:- both forwards, inwards or posteriorly. One may face forwards and one medially, one medially and one laterally or one forwards and one laterally.

With such variation of the renal mass and the collecting systems it is in no way surprising to find as much variation in the blood supply.

The relationship which the renal tissue, the pelves and calyces and blood vessels bear to one another may have an important bearing on the development of lesions affecting any of them. Where operative treatment is required no one part of the system is less important than the other. It is for that reason that aortography is so important and so helpful in the management of such cases.

In the present series three patients with this anomaly have been investigated.

Two of the cases were of the right-sided type and were very similar.

Case (14) A.L. Male aged 53

History

This man had suffered severe attacks of right-sided

abdominal pain for a year previous to examination in September 1954. The pain was at times acute but usually consisted of a dull ache in the right iliac fossa. There were no associated urinary symptoms.

Urological Investigation

The condition was not considered to be appendicular in origin and examination of the urinary tract was undertaken in another hospital.

Clinical examination showed that there was a tender firm mass in the right iliac fossa.

An excretion urogram demonstrated two renal pelves in the right lower abdomen with no evidence of functioning renal tissue on the left side.

The diagnosis of crossed ectopia was made by a urological colleague who referred the patient to me for angiographic examination.

Aortography was performed on 20.9.54.

The arteriogram (Fig. 31) shows a right renal artery arising at the level of the 3rd lumbar body to supply the upper and outer portion of the fused kidney.

The aorta bifurcates just below this in an irregular asymmetrical fashion. A second renal artery which supplies the crossed left kidney arises from the bifurcation and runs out parallel to the right common iliac artery which is displaced by the renal mass.

The nephrogram (Fig. 32) shows the size, shape, position and component parts of the fused renal tissue. Junction has taken place along the medial border of each kidney, the right overlapping anteriorly a small part of the left.

No operation was considered necessary on this patient.

Case (15) C.H. Female aged 56

History

This woman was admitted to a General Surgical Unit in December, 1954. She had suffered from frequent attacks of vomiting and diarrhoea for the previous four weeks. There were no symptoms referable to the urinary tract.

Clinical examination revealed a tender mass in the right side and right iliac fossa. This was considered to be either an appendix abscess or an ectopic kidney. The gastro-intestinal symptoms settled and the latter diagnosis was considered more probable. The patient was therefore referred direct for aortography, no other radiological examination having been done.

Aortography was carried out on 13.12.54.

The arteriogram (Fig. 33) shows that the right renal artery arises from the aorta at the lower border of the 3rd lumbar vertebra. It is of normal calibre and divides outside renal tissue, the major division continuing down in the sulcus between the kidneys to enter the medial aspect of the right

kidney.

The blood supply to the left kidney consists of a vessel of good size arising from the anterior aspect of the aorta above its bifurcation between the 3rd and 4th lumbar bodies. In the beginning it overlies the right common iliac artery before dividing to run down on each side of it. In addition there is an accessory vessel arising from the left common iliac above its bifurcation which supplies the lower pole of the left kidney.

The nephrogram (Fig. 34) shows that the kidneys are joined at an acute angle, the upper pole of the left kidney being fused to the hilum of the right kidney.

Although no other radiological investigation was undertaken, the information gained by the arteriogram, nephrogram and the late films of the excretion urogram in this one examination were adequate for complete diagnosis.

Case (16) A.M. Male aged 32

History

This patient was admitted to a General Surgical Unit complaining of severe left-sided pain. This had been intermittent but severe and appeared to be in the nature of renal colic. He had no other urinary symptoms.

Excretion urography was done on 8.4.54 which suggested "a stone in the left ureter. Both pelves appear

to lie on the left side of the abdomen."

The patient was sent to the Urological Department for further examination.

Urological Investigation.

Clinical examination showed a fairly large easily palpable mass in the left abdomen. It moved freely on respiration but the margins were ill-defined.

Cystoscopy on 13.4.54 showed no abnormality of the bladder. The ureteric orifices were normal in size, shape and position. Catheters were passed up each ureter and retrograde urography carried out. This showed crossed renal ectopia to the left. The larger upper pelvis showed some dilatation as did the calyces. No stone was present.

In view of these findings, especially the presence of slight dilatation of the upper segment, the question arose whether resection of the upper segment should be done.

It was thought advisable to carry out aortography to determine the vascular supply. This was done on 18.4.54.

Arteriography shows (Fig. 35) that there are three vessels arising from the left side of the aorta which run out to supply part of the left renal mass. The largest of these which arises at the 2nd lumbar body resembles a normal renal artery. The other two which arise one vertebra higher are of equal size and run out parallel to each other to supply the upper part of the mass.

In addition to these there is a right renal artery which takes origin from the right side of the aorta at about the same level as the largest left artery. This vessel crosses the aorta and supplies the lower part of the fused renal tissue.

Study of the nephrogram (Fig. 36) reveals a most interesting state of affairs and in some respects it is the most valuable film in this case.

The left kidney appears to be hypertrophied and elongated but otherwise a normal kidney. The right kidney however, is quite small (about half the normal size) and is attached to the lower half of the medial border of the left kidney.

Consideration of these films, arteriogram and nephrogram, shows that the contemplated resection of the supposed upper segment containing the slightly dilated pelvis would have been quite wrong.

Had this, in fact, been carried out it would have resulted in one of two things. Either the lower half of the left kidney would have ceased to function because its pelvis had been removed and there would have been no communication between the lower calyces of the left kidney and the right renal pelvis. Or, on the other hand, a urinary fistula would have developed. In either event the remaining small segment of right kidney might not prove capable of permanent normal

excretory function.

Under these circumstances no operation was performed.

This was a most interesting case which illustrated the value of angiography, especially in the demonstration of the parenchymal tissue. In this respect the urograms did not indicate the amount of tissue drained by the separate collecting systems.

DOUBLE KIDNEY.

Congenital anomalies of the ureter are commonplace and the great majority are of no clinical significance.

In others, however, obstructive and infective lesions of the upper urinary tract are associated with them and in these circumstances they become of surgical importance.

The abnormality of the ureter may take many forms but where there is duplication of the renal pelvis and upper ureter the term double kidney is applied. This infers duplication of the pelvis and also of the ureters although in the latter case this may be incomplete or complete.

The type of termination of the ureter is of little

importance as regards arteriographic investigation as the information so gained is confined to the kidney. In this respect the anatomical considerations relating to the kidney are as follows:-

There may be no line of demarcation either externally or internally of the parenchyma denoting the separation and size of the two halves. Where such is present it takes the form externally of a groove or furrow of variable depth which on section may be seen internally to correspond to the line of fusion. In these cases it may be demonstrated by the nephrogram. The size of the segments of the kidney is not constant or regular but in the majority of cases the upper segment is smaller and represents about one-third of the total kidney.

The majority of patients with a double kidney are found to have that condition almost accidentally in the course of urographic examination. These patients have few symptoms in any way referable to the condition.

Others, however, do present with signs and symptoms directly attributable to lesions present in the anomaly. In such cases one or other of the segments of the kidney may show infection or dilatation. These pathological processes in turn lead to secondary atrophic changes and the combination of the infection, dilatation and secondary hypoplasia is associated with the production of pain.

The occurrence of dilatation and infection has in the past been ascribed entirely to mechanical causes. There is little doubt that this is so in many instances and there are several obvious reasons for such a supposition. For example, it is by no means uncommon for the duplicated ureters to cross and produce a definite mechanical obstruction. The insertion of one ureter into the bladder may be abnormal. Accessory blood vessels may obstruct one of the ureters or there may be defective peristaltic movement.

It is not unreasonable to suggest that another explanation may be possible to account for the frequency of infection and pain in one of the segments of a double kidney. Any renal anomaly is frequently associated with an abnormality of the blood supply. If the vascular distribution to one segment be deficient this may well contribute to the development of disease. Any ischaemic area will have a lowered resistance to the early onset of infection and permit progressive pyelonephritis.

Proof of such a theory is difficult as the occurrence of pyelonephritis or hydronephrosis leads to a progressive vascular obliteration and it is not by any means easy to determine whether the poor blood supply is primary or secondary. In this respect the appearance of the angiogram is as conclusive as the histological findings.

The importance of arteriography in cases of pelvic

duplication lies in its surgical application. When pain is a feature, whether due to infection or dilatation of one segment, the removal of that segment may be necessary. It is not only unnecessary but undesirable to perform complete nephrectomy.

In such cases resection or partial nephrectomy is the procedure of choice. It is my opinion that aortography should be done before such operations of a conservative nature as the information is extremely helpful.

In the case of pelvic duplication a double blood supply, each arising direct from the aorta, is not uncommon. The distribution of this blood supply is readily recognised and ligation of the main supply to the affected segment may be performed outwith the kidney before the latter is sectioned. The resultant diminution in haemorrhage simplifies the subsequent surgical manoeuvres. Further reference to this will be made in connection with resection of the kidney for other lesions.

In the present series examples of both unilateral and bilateral double kidney have been investigated.

Unilateral Duplication.

Case (17) A.K. Female aged 32

History

This woman was first seen as an outpatient on 15.10.54

She had suffered an attack of pain in the left loin three months previously which had been diagnosed and treated by her own doctor as pyelitis. There had been temporary improvement following Sulphonamide therapy but the pain had returned and was constant in the left renal angle. In addition she felt pain in the left iliac fossa. She had no frequency or haematuria.

Urological Investigation.

Excretion urography on 18.10.54 showed duplication of the left renal pelvis and upper ureter. The right side was normal.

Cystoscopy on 25.10.54 revealed two normal ureteric orifices. Retrograde pyelography on the left side (Fig. 37) confirmed the previous appearances. The ureter is double as far as the sacro-iliac joint. The upper pelvis and its ureter are slightly dilated.

It was considered that this dilated segment was responsible for the symptoms and that it was obstructed lower down.

Aortography was performed on 5.11.54 with the results seen in Fig. (38). The arteriogram shows that the otherwise normal right kidney has a double blood supply. The main vessel arises from the usual level in the aorta whilst an accessory vessel supplying the lower pole runs up from the upper border of the 3rd lumbar vertebra. On the left side -

the affected kidney - the blood supply is single and more or less normal.

The nephrogram (Fig. 39) shows a normal parenchymal outline of the right kidney and a large somewhat elongated outline of the left kidney in conformity with the usual findings in such a condition.

The superimposition of the ascending pyelogram on the arteriogram shows that the blood supply to the upper segment comes from the first major branch of the main renal artery.

The nephrogram unfortunately is obscured by gas in the bowel but the density of the upper pole is certainly less than that of the right kidney.

There is no obvious abnormality of the parenchymal outline suggested by a groove or lobulation.

It was decided to carry out resection of the kidney with removal of the upper segment.

Careful study of the arteriogram shows that while the blood supply to this segment arises from the upper major branch of the renal artery, this branch also sends an artery to the lower segment. Ligation should be employed distal to this last branch.

Operation.

At operation on 11.11.54 (A.J.) the pedicle was displayed but ligation of the whole upper major branch was

carried out close to its origin. This resulted in cyanosis of more than the upper segment and was associated with spasm of the main renal artery. This spasm was not the cause of the colour change which did not affect the whole of the kidney but only the area supplied by the branch previously mentioned and was still present at the end of the operation after the spasm had passed off. Some anxiety was felt about the progress of this case but her convalescence was uneventful.

Case (18) G.G. Male aged 45.

History

This man was referred for investigation following an attack of right renal colic. An X-Ray examination in the local hospital had suggested the presence of a stone in the right ureter.

Urological Investigation.

Excretion urography on 29.6.54 showed no opaque calculus but the outline of the right renal pelvis was not satisfactorily defined. The apparent irregularity of the pelvis and calyces raised the suspicion of neoplasm.

On 16.7.54 after admission to hospital, ascending urography showed that there was duplication of the right renal pelvis, the calyceal pattern being apparently normal.

Aortography was performed on 21.7.54 which shows (Fig. 40) no vascular abnormality of either kidney. No

accessory vessel is present on the affected side, the whole renal mass showing on the nephrogram satisfactory density of the dye throughout. No lobulation or demarcation line was seen.

This case was regarded as one of a minor congenital defect for which operation was not necessary.

Case (19) J.M. Male aged 29

History

This man was admitted to a Surgical Unit on 28.6.54 complaining of bouts of severe pain in the left loin over the previous few months. On examination it was considered that the pain was of renal origin and an X-Ray suggested that there was a small stone in the left kidney. He was referred to the Urological Department on 2.7.54.

Urological Investigation.

No clinical abnormality was found.

Excretion urography showed no stone but duplication of the left pelvis, the upper segment being small and dilated.

Ascending urography the following day confirmed these appearances.

Aortography was carried out on 6.9.54.

In this case the needle was inserted at the lower border of the twelfth thoracic vertebra and the whole content of the syringe was injected into the coeliac axis. (Fig. 7)

This case has already been discussed under Hazards. No information regarding the renal blood supply was of course obtained and a second injection was not performed as the effect of this mishap was not known at that time.

Bilateral Duplication.

Case (20) J.M. Female aged 54.

History

This woman was sent for examination as an outpatient on 8.12.54. She had suffered from attacks of severe right-sided pain over the previous two months. The pain appeared to be a renal colic.

There had been associated frequency of micturition but no haematuria.

Urological Investigation.

Clinically, the examination was essentially normal.

Excretion urography on 18.12.54 shows (Fig. 41) duplication of both renal pelves and ureters. The latter join to form one ureter on each side at the level of the 4th lumbar body.

The upper segments of each kidney are small as is usual but there appeared to be slight dilatation of that on the right side.

Aortography was done on 7.1.55 to determine the

renal vasculature, especially of the right upper segment.

The arteriogram (Fig. 42) shows that the left kidney is supplied by a single normal vessel. On the right side there is a large vessel also of normal size and origin supplying the major part of the kidney. In addition an accessory vessel of small calibre arises above it and supplies a small area of the upper pole.

The area of parenchyma around the upper right pelvis has an abnormal blood supply. This was confirmed on the nephrogram which did not show any marked sulcus between the segments.

Operative treatment was not recommended and the patient's symptoms disappeared. She has remained well since

Single Unilateral Fused Kidney

This is an uncommon condition but the following case may be regarded as this anomaly. It presents several interesting points and has already been published. (Stirling, 1953)

Case (21) A.O. Female aged 57

History

This woman complained of urinary symptoms in July 1952. She had frequency of micturition, dysuria and

suprapubic pain due to a urinary infection.

Excretion urography carried out in the local hospital showed dye concentration at two levels on the left side but none on the right. It was thought that this was a case of crossed renal ectopia and she was referred for full investigation of the urinary tract.

Urological Investigation

Clinical examination on 12.1.53 showed tenderness in the left loin, the kidney on that side being easily palpable. The urine was infected with B. Coli.

Cystoscopy on 13.1.53 showed a mild cystitis and the right ureteric orifice was not identified. Left ascending urography showed a single ureter entering the lateral aspect of the lower of two renal pelves. The upper small pelvis appeared to communicate with this lower malrotated one within the kidney and not by the junction of a separate ureter.

Braasch was the first to describe the occurrence of communication between the pelves of a double kidney and one further instance has been described by Emiliani. (1932).

On 11.2.53 aortography combined with presacral perinephric air insufflation was performed.

The early nephrogram (Fig. 43) shows that the left kidney is an elongated organ occupying an area between the 1st and 5th lumbar vertebrae. There is a double, equal supply to this renal mass, the main vessels being still visible on

this film.

Later films were taken to produce excretion urograms. This is illustrated in Fig. (44) which shows the excellent effect so produced. The communication between the small upper pelvis and the lower malrotated one is clearly demonstrated.

This is not considered to be an attenuated neck of calyx as there is a definite small pelvis into which drain two groups of calyces.

MOBILE KIDNEY

Moveable kidney or nephroptosis has been and remains a subject of much controversy amongst urologists.

There is no complete agreement regarding the causation or treatment of the condition.

The main supports of the kidney consist of the renal fascia and its septa and the vascular pedicle. The fatty capsule, the intra-abdominal pressure and various ligaments of other structures are of secondary importance.

The bodily make-up of the patient is important as the condition is commonly encountered in asthenic young women. In these individuals there is a general loss of muscle tone and a congenital predisposition to a shallow renal fossa and deficiency of the normal supports of the kidney.

Where mobility of the kidney is excessive it is found that the vascular pedicle is elongated and the ureter redundant. The pathological changes which occur may consist of a degree of hydronephrosis or the establishment of infection.

It is in the matter of treatment that considerable disagreement exists.

The extreme views of those who state that operation should never be performed are, however, more than balanced by those, especially in the past, who operated on every patient showing undue mobility.

In my experience operative treatment in the form of nephropexy is justifiable and usually successful when severe pain, renal crises or dilatation of the kidney, with or without infection, are present. Symptomless cases, concomitant visceroptosis or marked neurasthenia are contra-indications to surgical interference.

The diagnosis of the condition is made on clinical examination and urography, employing the technique of tilt films.

In the vexed question of treatment the use of arteriography may contribute to the proper selection of cases for operation.

One of the main difficulties lies in the assessment of pain. The classical Dietl's crises or severe pain in the presence of established hydronephrosis are easily recognised. Where no dilatation or infection can be found genuine pain may still exist. Apart from any temporary obstruction to the urinary outflow resulting from excessive mobility of the kidney there is a drag on the vascular pedicle when the organ descends. Whilst no proof can be offered it may be that this vascular "tug" is responsible for some of the pain found in certain patients. In addition, when the pedicle is long, a degree of torsion is possible which would result in acute renal congestion. If such be the case it may be that the length of the pedicle is of importance in assessing the type of treatment necessary.

In established nephroptosis there is elongation of the renal pedicle. The artery, however, arises near the normal site of origin from the aorta. This readily distinguishes the condition from that of ectopia where the vessels are shorter and arise lower in the aorta nearer the site of malposition of the kidney.

Renal angiography was performed on the following three patients in whom excessive renal mobility was present.

Case (22) J.O. Female aged 28

History

This patient was referred for examination on 28.7.54, with the complaint of severe pain in the right side. The pain had been present intermittently for six months and at times was extreme, apparently corresponding to Dietl's crises. The pain was distributed down the course of the ureter and across the back. One unusual feature was that she did not admit to any significant relief from pain on lying down.

Urological Investigation

Clinical examination on the same date showed the typical asthenia and constitution of those young women with renal ptosis.

The right kidney was easily palpable and quite mobile.

Excretion urography on 28.7.54 showed poor detail of the right kidney.

Ascending pyelography with tilt films was carried out on 3.8.54. This showed the right kidney to lie low and the excessive mobility was confirmed. The right renal pelvis showed dilatation and was angled to the ureter.

No surgical treatment was advised at that time and she was supplied with a surgical belt. This afforded her little relief and she was admitted to hospital for further assessment.

Aortography was carried out on 7.1.55.

The arteriogram (Fig. 45) shows that both renal arteries arise from the aorta within the normal limits. On each side the downward obliquity is greater than usual, both kidneys lying lower then the normal. This downward displacement is greater on the right side - the main vessel being considerably elongated. The branches from it give the impression of being stretched.

The parenchymal distribution and the nephrogram appeared normal. This appearance is typical of nephroptosis as opposed to ectopia.

Operation

In view of the radiographic and clinical findings right nephropexy by the Thomson-Walker technique was carried out on 11.1.55. (W.B.S.)

The immediate result of this has been excellent, the patient having been relieved of all discomfort and she has remained well since.

Case (23) E.C. Female aged 57

History

This patient was first seen in 1951 complaining of intermittent attacks of pain in the right loin. Excretion urography was indefinite and right ascending pyelography suggested a degree of renal ptosis. As she had recently undergone operations on the gall bladder and appendix no further surgical treatment was recommended. She was examined two years later still complaining of right-sided pain and ascending urography did not indicate any appreciable descent of the kidney but the catheter was placed well within the renal pelvis. She was sent for further examination on 24.10.55 having experienced considerable right-sided pain for several weeks.

Urological Investigation

On clinical examination the right kidney was palpable and tender. The pain appeared to be relieved on lying down.

Ascending pyelography was repeated on 2.11.55 with tilt-up films and shows (Fig. 46) that the kidney is low-lying and appears to have rotated on the transverse axis. The descent of the kidney between extreme tilts, however, was no

more than the distance of one vertebral body and doubt remained whether the condition was entirely one of ptosis or associated ectopia.

In an attempt to elucidate this, aortography was performed two days later.

This shows (Fig. 47) that the right renal artery has a normal level of origin at the upper border of the 2nd lumbar body. The main divisions arise some distance from the renal hilum and are themselves of considerable length. These appearances indicated that the condition was not one of ectopia and that the renal pedicle was of considerable length and could allow a large range of movement both in the vertical and transverse planes.

It was considered that her pain was genuine and could be relieved by nephropexy.

Operation.

The right kidney was explored on 8.11.55. (W.B.S.) The kidney which appeared to be normal had a considerable range of movement and the length of the vascular pedicle was confirmed. Accordingly a Thomson-Walker nephropexy was performed and it was possible to fix the upper half of the kidney above the 12th rib.

Aortography proved of some value in this case by demonstrating that the position of the kidney on urography was

entirely due to renal mobility and not to congenital ectopia. The redundancy of the pedicle was shown and the feasibility of high fixation clearly demonstrated.

The third patient proved an interesting comparison.

Case (24) I.M. Female aged 51

History

This woman was seen as an outpatient on 1.10.54 complaining of right-sided pain radiating to the groin. The pain which was intermittent had been present for two years. There was associated frequency and dysuria. She stated that she lost the power of the right leg when the pain was present. She had a long surgical history which included four major abdominal operations.

Urological Investigation

Excretion urography on 4.10.54 showed that the right kidney pelvis lay at the level of the 3rd lumbar transverse process. As detail of the kidney was not good a right ascending pyelogram was done on 25.10.54. This confirmed that the kidney lay lower than usual but was otherwise normal, no dilatation being present.

Three months later excretion urography was repeated with no change in the appearances and as she continued to complain of pain she was admitted to hospital.

Aortography was carried out on 17.1.55 and shows (Fig. 48) that both renal arteries arise fairly high at the upper border of the 2nd lumbar body. The larger right artery is more elongated but does not approach the length of that seen in the first patient.

The nephrogram (Fig. 49) presents an interesting appearance. It shows that the right kidney lies lower than normal. There is, however, a persistence of the foetal polar approximation which exaggerates the appearance of ptosis.

In view of the absence of dilatation, limited mobility, bad previous surgical history and definite neurasthenia no operative treatment was undertaken. In addition to this, however, the length of the pedicle whilst greater than normal was not considered excessive.

Comparison of these cases confirms that the degree of movement of a kidney is related to the length of the vascular pedicle.

It is not possible to state from these examinations whether in mobility of the kidney the elongation of the artery is the primary factor or is secondary to the excessive mobility.

Aortography, however, appears to be a useful additional method of assessing the desirability of carrying out a suspension fixation operation.

CYSTIC KIDNEY.

There are two main types of cyst formation of the kidneys which are of clinical importance. These comprise the solitary cyst and the multilocular cystadenoma - polycystic kidney.

Solitary cyst of the kidney is uncommon but in the past presented problems in diagnosis. The condition is usually unilateral and when symptoms occur they may consist of pain in the side and back and haematuria.

There is no characteristic symptomatology nor are the urographic appearances absolutely diagnostic. As regards the latter, both excretion and ascending methods may show no change in the urogram to distinguish from the normal. Where deformity exists it may take the form of the following:-

Displacement of a calyx alone or of ureter or both.

Filling defect of one or more calyces or of pelvis.

Elongation and dilatation of calyces.

Appearances as in simple hydronephrosis.

It is evident that none of these are characteristic of cyst. They are all found in neoplasms of the kidney and hence arise the frequency of erroneous diagnosis in these cases.

Reference to this is made under the discussion regarding renal neoplasms.

The arteriographic appearances found in cases of

simple cyst are quite characteristic. The main nutrient vessel to the area of kidney occupied by the cyst is small and thin. The terminal branches are widely displaced in a smooth regular umbrella-like fashion. No small vessels can be seen rising from these branches into the area.

It is in the nephrogram, however, that the most typical diagnostic appearances can be seen. The clear fluid of the cyst which is quite avascular presents as a translucent, smoothly-contoured area of parenchymal deficiency. This is quite distinct and unmistakable and is exactly opposite to the appearances of a solid neoplasm.

This definite diagnostic difference between neoplasm and cyst is of considerable practical importance. It can only be achieved by arteriography and was one of the earliest indications advanced by dos Santos for the use of aortography in renal diagnosis.

In the present series one case only has been investigated.

Case (25) A.H. Male aged 47

History

This man was admitted to a Medical Unit for investigation of dyspepsia. On clinical examination the right kidney was palpably enlarged. There were no symptoms referable to the urinary tract. Urography showed distortion

of the lower major calyx group. The appearance suggested more the presence of cyst than neoplasm.

He was referred for further investigation and aortography was carried out on 21.10.53. This showed the major supply on the right side to be normal but towards the lower pole the branches were distracted in a smooth regular umbrella fashion.

The nephrogram showed the parenchymal outline with a smooth swelling at the lateral aspect of the lower pole. This was relatively translucent compared with the remainder of the kidney.

A confident diagnosis of cyst was made. Absolute confirmation, however, is not possible.

Operation was not considered necessary and in any case the patient refused any surgical treatment.

It is regretted that these pictures are not suitable for reproduction having been damaged.

POLYCYSTIC KIDNEY.

This condition of congenital origin and familial association is almost always bilateral.

The symptomatology is variable and extensive, including renal insufficiency, lumbar pain, haematuria and a palpable tumour in one or both loins.

The diagnosis in the established case is usually simple on clinical and radiological grounds. The urographic changes depend on the degree to which the disease has advanced. In the early stages there may be only a slight elongation and narrowing of the major calyces whilst in the more advanced case the bizarre appearance of the elongated compressed calyces gives rise to the term "dragon deformity".

The bilateral nature of the disease is helpful in reaching a diagnosis in many cases but where the disease is much more advanced on one side, doubt may remain regarding the exact nature of the condition. In these cases aortography may prove helpful.

Four cases of polycystic disease of the kidneys have been investigated in the present series.

Case (26) T.S. Male aged 52

History

This man was first seen on 8.7.54 as an outpatient.

He had suffered from intermittent attacks of mild haematuria for the previous four months. He had no pain and no other associated urological symptoms.

Extensive investigation consisting of cystoscopy and urography on four occasions had been carried out at another hospital without a definite diagnosis.

Urological Investigation.

Clinical examination revealed no abnormality, neither kidney being palpable.

Excretion urography on 8.7.54 showed some "splaying out" of the upper right calyces, no detail being obvious on the left side.

Cystoscopy on 15.7.54 was normal and bilateral ascending films showed that all the right calyces were somewhat bizarre, these changes also affecting the left upper group. It was considered that this was a case of early polycystic disease.

In order to determine what changes, if any, would be seen on arteriography and nephrography, translumbar aortography was carried out on 3.9.54.

The arteriogram (Fig. 50) shows minimal changes in the vascular distribution but it is interesting to note that the blood supply to the right kidney, apparently more affected on urographic examination, was better than that of the left kidney. Close examination shows a slight regular displacement

of some of the interlobar branches and a slight relative deficiency in the vascularity of the lower pole of the left kidney and upper pole of the right.

The nephrogram presented a somewhat mottled appearance due to variations in density even more marked on the left side. These appearances, however, by themselves are not diagnostic.

This patient is an example of early polycystic change in which the urographic and arteriographic appearances are not striking.

Case (27) D.W. Male aged 35.

History

This patient gave a history of intermittent haematuria over the previous nine years. This was associated with pain in the left loin. Haematuria was last seen a week before examination.

An exploratory operation had been performed on the left kidney five years previously in Malaya. He said that he was told that there was "some cystic condition, probably polycystic" present.

Urological Investigation.

Clinical examination on 22.10.54 showed no abnormality apart from a left renal scar.

Cystoscopy was carried out on that date which showed a normal bladder appearance.

Excretion urography was carried out and showed the right kidney to be apparently normal apart from a degree of bifid pelvis. On the left side the dye excretion was not good and there was apparent distortion of the calyces.

Left ascending urography on 2.11.54 confirms this bizarre appearance (Fig. 51) which, however, is not typical of polycystic disease. The lower medial calyx has, however, one smooth round indentation. The fact of a previous operation on that kidney had to be taken into account.

Aortography was done on 7.2.55 to see if this would afford any further information.

The arteriogram (Fig. 52) shows on the left side some thinning and displacement of the major branches. This is particularly marked in the lower part. This appearance, however, can not be regarded as absolutely typical of polycystic disease as a similar appearance is present in hydronephrosis of the intra-renal type.

On the right side the blood supply is almost normal although there is one small area towards the upper pole where there is a regular minor displacement of the interlobar branches.

The nephrogram showed some enlargement of the left parenchymal outline, especially at the lower pole but this was

quite regular. There were no discrete translucent areas.

The diagnosis here remains somewhat equivocal and angiography was no more specific than urography.

The patient has not reported back and his further progress is not known.

Case (28) G.W. Male aged 45

History

This patient had suffered a temporary aphasia and left-sided paresis some months previous to attending the Urological Department on 8.12.54.

He was found to have high blood pressure - 200/120 mm./Hg.

Urological Investigation

Clinical examination confirmed the hypertension. Both kidneys were easily palpable and considerably enlarged.

Excretion urography on 8.12.54 showed only very faint excretion from each kidney and no detail could be made out. The presumptive diagnosis of polycystic disease of the kidneys was made.

The patient did not complain of pain in either kidney but as the condition appeared to be fairly advanced the question of surgical treatment in the form of Rovsing's operation was considered. The rationale of this procedure

lies in the possibility of relieving tension to such a degree as to permit some temporary improvement in renal function.

In order to assess, if possible, the difference of degree in each kidney, aortography was done on 29.1.55.

The arteriogram shows (Fig. 53) the typical appearance of advanced polycystic disease.

Beyond the main arteries there is gross deficiency of vascularity. Not only the branches but the major divisions are compressed and displaced in a smooth, regular fashion. This is more marked on the left side.

The nephrogram was very faint owing to this deficient blood flow, neither parenchymal outline being fully defined. No discrete areas of relative translucency could be made out.

The arteriogram in this case certainly afforded definite confirmatory evidence of the clinical diagnosis. Whilst this was lacking on excretion urography it could however have been determined on retrograde examination. Angiography, however, did afford information regarding function not possible by the latter method.

Case (29) P.M. Male aged 59

History

This man had undergone a right herniorraphy fourteen

days previously in the general surgical wards. He had been found to have a palpable right kidney and X-Ray showed calculus-like shadows in the left renal area. He was referred for urological investigation.

Urological Investigation

Excretion urography on 14.12.54 showed no function on the right side whilst on the left side there appeared to be gross hydronephrosis and several large stones present.

As the condition of the right kidney was not known retrograde urography was attempted on 18.12.54 but failed as the ureteric catheter could not be made to pass up the ureter.

Aortography was therefore carried out on 20.12.54 to provide further information.

The arteriogram (Fig. 54) is of rather poor quality, this patient being extremely stout.

On the right side the blood supply is grossly deficient, hardly extending beyond the edge of the vertebral column. The left renal artery is of normal size but the vascularity of the lower part of the kidney is extremely poor. The two terminal divisions are thinned and displaced in a regular arc.

As was to be expected there was no appreciable nephrogram on the right side and only a very faint parenchymal outline of an enlarged left kidney.

As the right kidney was avascular and non-functioning

it was decided to remove the stones from the left kidney in order to increase its efficiency.

Operation.

The left kidney was explored on 21.12.54. (W.B.S.) It was found to be grossly hydronephrotic and in addition to be polycystic.

The stones were removed, the cysts punctured and nephrostomy drainage instituted.

His convalescence from this was satisfactory but three weeks later he had a perforation of a duodenal ulcer. He was transferred back to the General Surgical Wards where operation was undertaken but he died two days later.

Post-mortem examination showed advanced polycystic disease of the kidneys. There was no evidence of the aortic puncture.

In this case the presence of polycystic disease was not shown by angiography, which demonstrated, however, the actual and potential renal function.

SUMMARY AND CONCLUSIONS.

The results in the various congenital anomalies confirm the claim that angiography can provide information of practical value not possible by other methods.

Solitary Kidney.

The appearances are quite specific. There is complete absence of any arterial segment on the affected side, the aortic wall being regular and unbroken. In the difficult case where two ureteric openings are present in the bladder the above appearances are diagnostic. They serve to distinguish the condition from hypoplasia in which, as in nephrectomy, the stump of origin of the renal artery or a notch in the aortic wall is present.

Ectopia.

Such conditions, whether simple or crossed, present many variations in blood supply. The knowledge of the number, course and distribution of the arteries may be of considerable help where surgery is contemplated.

Arteriography provides a differentiation between ectopia and ptosis.

The nephrogram will determine the presence or absence of renal fusion. In the former case the size, shape and position of the component parts are shown. This may, as in Case (16) influence the surgical treatment.

Fusion.

The same considerations apply in horseshoe kidney as in ectopia. A distinction, not possible on urography, may be made between fusion and bilateral incomplete rotation.

The feasibility of fixation operations is shown.

Double Kidney

Angiography has a limited application in the diagnosis of this anomaly but is of practical value in demonstrating the blood supply to the two halves of the kidney.

Mobile Kidney

Apart from distinguishing ptosis from ectopia the demonstration of the length of the vascular pedicle may contribute to an assessment of those cases suitable for operative treatment.

Cystic Disease.

Angiography is of very limited value in the polycystic type. In the early stages the arteriographic changes are minimal and in the late stages are dependent on a patent vascular tree. The nephrogram seldom shows many areas of translucency comparable to the solitary cyst because the numerous cysts do not occupy the whole thickness of the renal parenchyma.

It is of considerable value in the solitary cyst and will distinguish that condition from parenchymal neoplasm.

RENAL NEOPLASM.

The demonstration of renal neoplasm was one of the earliest diagnostic findings of renal arteriography and remained for many years one of the few definite indications for the employment of aortography.

The appearances of the arteriogram and nephrogram are typical and definite and are related to the degree of vascularity of the tumour.

The majority of solid renal neoplasms may confidently be diagnosed by the usual urographic methods. In a number of cases, however, neither excretion nor ascending urography can determine the exact nature of the space-occupying renal lesion. This is particularly so in the distinction between neoplasm and cyst of the kidney. The following extract from "An Atlas of Roentgenologic Diagnosis" by Braasch and Emmet of the Mayo Clinic, published in 1951, reflects the view still held by many surgeons.

"To illustrate the futility of trying to differentiate cyst from tumour, the following illustrations of cysts simulating tumour are presented..... It is obvious surgical exploration is the only safe procedure."

Such a statement is no longer true.

Arteriography and nephrography provide a sure distinction between them and indeed is the only method by which

such a definite diagnosis may be made, apart from surgical exploration or blind puncture of the kidney.

In brief, the solid tumour shows increased vascularity and density whilst the fluid cyst presents as an area of deficient vascularity and increased translucency within the kidney substance. Thus the difference between them is striking and unmistakable.

The adenocarcinoma of parenchyma is by far the commonest space-occupying lesion of the adult kidney.

Riches (1951) in a review of 2,100 cases of renal tumour provided by members of the British Association of Urological Surgeons, found that 83.5% consisted of adenocarcinoma.

It is not surprising therefore that most of the descriptions of renal tumour apply to this type.

In the present series eight cases of adenocarcinoma have been investigated, but other types of tumour have also been encountered and will be discussed.

1. Parenchymal adenocarcinoma.

This tumour has a well-known gross appearance displaying pseudo-capsulation, pseudo-cyst formation, yellow lipoid areas and haemorrhagic areas. It is a vascular growth and blood sinuses are usually present. These pathological

changes are reflected in the angiographic findings.

The arteriogram of a kidney affected by such a tumour of reasonable size shows hypertrophy of the main renal artery and its major branches. This hypertrophy is most easily assessed by comparison with the contra-lateral side. The nutrient branch or branches to the tumour area are thickened and displaced by the mass of the growth. There is a collection of dye of good density within the vascular sinuses. To this the term "pooling" or "laking" of dye has been given. This appearance of "pooling" is quite diagnostic of a vascular tumour of the parenchyma.

The nephrogram shows a persistence of this dye condensation. In addition to the "pooling" it will outline the size of the mass and illustrate its relation to the kidney.

The configuration of the renal mass so demonstrated is superior to that obtained by urography. The results of perinephric air insufflation which is useful in assessing fixation of the tumour are enhanced by a good nephrogram.

There may be some difference in the degree of "pooling" between the arteriogram and nephrogram. In some cases it is more marked in the former whilst in others it may be more pronounced in the latter. In the case of the old tumour in which central degeneration and necrosis have taken place with cyst formation the appearances may not be quite so definite. Careful inspection will reveal some degree of

increased vascularity and "pooling" at the periphery which will serve to distinguish the condition from that of simple cyst. There is one pitfall in the distinction between tumour and cyst, namely, where a papillary cystadeno-carcinoma exists within a cyst.

There are two references in the literature to this rare condition.

Creevy and Price (1955) failed to demonstrate such a lesion and were critical of the value of angiography in this connection.

On the other hand, Reagan and Carroll (1951) clearly demonstrated pooling round the periphery of a cyst and correctly diagnosed the condition by this method.

No opportunity has arisen for personal examination of such a case, which may well prove extremely difficult to diagnose. Much depends, however, on the quality of the films and the interpretation.

Apart from such a distinction between tumour and cyst there remains a number of cases in which neoplasm is suspected but not positively identified by urography. Such instances are few where the interpretation is made by experienced urologists or radiologists but they do occur from time to time.

Aortography, by providing confirmatory or exclusive evidence, either of which is important, may prove of considerable value and avoid procrastination or unnecessary

operation.

The following case is a classical example of the angiographic appearances in an advanced tumour of this type.

Case (30) A.R. Female aged 68

History

This woman was seen as an outpatient on 31.8.54. She had noticed that the urine was deeply bloodstained on two occasions within the previous four weeks. She had suffered an attack of left-sided colic two weeks before that which she ascribed to a "chill on the kidneys". She had no frequency or difficulty of micturition.

Urological Investigation.

On clinical examination on 31.8.54 the left kidney was palpable but not tender.

Cystoscopy showed no abnormality within the bladder and there was a clear efflux from each ureteric orifice.

Excretion urography on 3.9.54 showed the right kidney to be normal.

On the left side, the concentration of the dye was poor and there was incomplete filling of the calyces. The latter, however, appeared to be elongated and distorted. A provisional diagnosis of parenchymal neoplasm was made.

Aortography on 11.9.54 confirmed the diagnosis.

The arteriogram (Fig. 55) shows that the left renal artery is considerably enlarged. The distal half and the major divisions are displaced medially. There is obvious pooling of the dye around most of the upper division and at the termination of the lower one. Further irregular pooling is seen towards the upper pole.

The nephrogram (Fig. 56) clearly demonstrates the extent of this pooling and its persistence within the vascular sinuses. In addition the total renal mass is defined. This was not obvious on the urogram or arteriogram.

Operation.

At operation on 13.9.54 (A.J.) the tumour was found to correspond to the nephrogram findings. Almost the whole of the kidney was replaced by a large malignant growth - 15 x 11 cm.

Histology confirmed that this was a clear-cell parenchymal adenocarcinoma.

Whilst in this case, clinical and urographic examinations afforded a fairly definite diagnosis, aortography left no doubt whatsoever.

Case (31) M.C. Female aged 69.

History

This woman sustained an injury to her right side on

16.7.55. This was followed by persistent haematuria and the passage of blood clots. She had no haematuria before the accident. She was admitted to a General Surgical Unit as a case of renal injury.

The initial pain in the right loin subsided within 24 hours and was succeeded by pain in the left loin. Haematuria was persistent and in view of this she was referred for further detailed examination.

Urological Investigation.

Clinical examination on 22.7.55, six days after the accident, showed that she was tender in the left renal angle. No palpable enlargement of either kidney could be made out but the patient was very stout. She made no complaint of pain on the right side.

Excretion urography on that date was not very satisfactory owing to poor concentration of the dye and the stoutness of the patient.

Cystoscopy, however, showed that the bladder was normal but that there was a definite blood-stained efflux from the right ureteric orifice.

Bilateral ascending urography was performed on 26.7.55 by which time haematuria had ceased. The right pyelogram showed incomplete delineation of the upper calyces suggesting the possibility of renal neoplasm, the left kidney being quite normal. (Fig. 57)

In view of the occurrence of injury on that side, the diagnosis of neoplasm was not definite and consideration had to be given to the possibility of trauma being responsible for the pyelographic appearances.

Accordingly, aortography was done on 29.7.55 to obtain fuller information.

The arteriogram (Fig. 58) shows that there is a normal main blood supply to each kidney. On the right side the renal artery is, however, slightly enlarged. On each side of the terminal branch from the upper division there is an irregular area of pooling. In addition to this, a faint outline of a broadened, enlarged, upper pole is discernable. This was confirmed on the nephrogram. These appearances were considered to be definitely indicative of neoplasm and operation was advised.

Operation.

At operation on 2.8.55 (W.B.S.) this diagnosis was confirmed. The tumour which had replaced the upper half of the kidney measured 6 x 7 cm. On naked eye examination two vascular sinuses were present corresponding to the areas of pooling seen on the angiogram.

Histological examination confirmed that this was a parenchymal adenocarcinoma.

This proved an interesting example of renal tumour in

which few symptoms referable to it arose until an injury. The exclusion of trauma as the cause of the bleeding was only possible after a full urological investigation in which angiography played an important part.

Case (32) D.D. Male aged 62.

History

This man was examined as an outpatient on 24.1.53, two days after an attack of severe right renal pain. This was associated with profuse haematuria and these symptoms had been present intermittently for ten days previously.

Urological Investigation.

On clinical examination, a mass was palpable in the right loin. Cystoscopic examination revealed no abnormality there being a clear efflux from each ureteric orifice.

Excretion urography on that date showed no function on the right side, the left kidney being apparently normal although detail was poor.

Bilateral ascending urography was carried out on 24.4.53 which again showed a clear efflux from each kidney. The right pyelogram showed distortion of the lower major calyx group, the left side being normal.

A diagnosis of right renal tumour was made.

The patient was admitted to hospital and on 15.5.53 aortography was carried out.

The arteriogram (Fig. 59) which is a late phase does not show the renal vessels with the clarity usually obtained. In addition to the delay in exposing the film, injection was made by hand pressure. It does, however, clearly demonstrate pooling of the dye in several well-defined areas between which there is a patchy condensation in the lower part of the kidney. This is seen to consist of a fairly large mass.

Arrangements were made for operation some days later but the patient developed pneumonia and his condition rapidly deteriorated. He died six days later and post-mortem examination confirmed a large adenocarcinoma of the right kidney. In addition to this secondary malignant deposits were present in both lungs and adrenal glands.

Case (33) W.G. Male aged 52.

History

This patient was admitted to a Medical Unit in September, 1953 for investigation of loss of weight. He complained of some abdominal pain in the epigastrium. Clinical examination confirmed recent loss of weight, a low-grade pyrexia and a tender, palpable right kidney. Excretion urography showed no excretion from the right kidney, the left being apparently normal. He was referred for further urological investigation.

Urological Investigation.

Excretion urography was repeated on 10.10.53 with a similar result.

Cystoscopy on 13.10.53 showed no bladder abnormality and right ascending pyelography showed distortion of the middle group of calyces. A diagnosis of parenchymal tumour was made on these findings.

Aortography combined with perinephric air insufflation was performed on 22.10.53.

The arteriogram, one of the early films with hand pressure, was not very satisfactory.

The nephrogram (Fig. 60) clearly defines the outline of an enlarged renal mass - this is enhanced by the perinephric air insufflation which shows that the tumour is not fixed. Pooling is not very marked, appearing only as a slight condensation in the upper part overlying the twelfth rib.

Operation.

Right nephrectomy on 2.11.53 (A.J.) confirmed these findings. Examination of the specimen showed that it was a relatively avascular tumour thus accounting for the minimal pooling in this large mass.

Histology showed that it was a clear-cell adenocarcinoma.

Case (34) A.M. Female aged 62.

History

This woman was referred for examination on 16.9.55. She had suffered pain on micturition associated with frequency for the previous six weeks. During this period she had noticed blood in the urine on several occasions, and had also experienced some backache, especially on the left side.

Urological Investigation.

No significant abnormality was found on clinical examination.

Excretion urography afforded no information, the concentration being poor on each side.

Cystoscopy three days later showed no abnormality of the bladder and bilateral retrograde urography was carried out. The lower calyces of the left kidney were not well defined.

She was admitted to hospital later and on 3.10.55 left ascending pyelography was repeated. This shows (Fig. 61) some distortion of the calyceal pattern, the lower major calyx being broadened and elongated. This raised the suspicion of neoplasm.

Aortography was performed on 5.10.55.

The arteriogram (Fig. 62) shows on the left side a remarkable increase in the vasculature of the lower part of the renal hilum. This consists of numerous irregular branches.

Beyond this towards the lower pole there is an absence of branches except at the periphery.

The nephrogram (Fig. 63) shows an irregular outline of the left kidney. Almost three-quarters of the total mass consists of an area of increased density with an uneven outline. This area appears to be well demarcated from the upper portion of the kidney which appears to be somewhat flattened and compressed.

These appearances suggested that a definite parenchymal neoplasm was present and of greater extent that the urograms suggested.

Operation.

Left nephrectomy was performed on 7.10.55. (W.B.S.) The angiographic appearances were confirmed in that an adenocarcinoma, 7 cm. in size, was found to replace the middle and lower thirds of the kidney. The tumour was particularly vascular in its upper medial portion corresponding to the increased density shown on the arteriogram and nephrogram. The central and lower portions, however, contained no large vascular blood sinuses. Normal parenchymal tissue was restricted to a small upper polar part of the mass and was apparently separated from neoplasm by compressed tissue forming a pseudo capsule.

Histology confirmed that this was a parenchymal adenocarcinoma of the kidney.

Case (35) P.H. Male aged 45.

History

This man was sent for investigation on 14.10.55. He had suffered intermittent attacks of urinary frequency and dysuria along with occasional haematuria for the previous three weeks. The bleeding had not been severe. He had also suffered some low back pain, more marked on the left side.

Urological Investigation.

No significant clinical abnormality was found.

Cystoscopy showed no bladder abnormality and the urine was not blood-stained.

Excretion urography the same day showed no evidence of stone but the dye concentration was poor on each side and no opinion could be expressed regarding the integrity of either kidney.

On 18.10.55 bilateral ascending pyelograms were obtained, the urine again being free from blood on cystoscopy. These show (Fig. 64) the right kidney to be normal whereas there is deformity of the upper calyx group on the left side. A diagnosis of renal tumour affecting the upper pole of the left kidney was made.

He was admitted to hospital later and aortography performed on 11.11.55.

The arteriogram showed no appreciable enlargement of the main renal artery and no evidence of pooling anywhere in

the kidney.

The nephrogram, however, (Fig. 65) presents an interesting picture. The left kidney has a somewhat irregular outline and in the lower half there is a very definite round dense shadow, the kidney above this being broadened.

These appearances did not conform to the pyelographic changes and so a further retrograde pyelogram was done on 15.11.55. This was almost identical with the previous pyelogram and was reported as tumour affecting the upper pole. In spite of this it was felt that the nephrogram shadow was so distinct and obviously pathological that the tumour lesion lay in the lower part of the kidney.

Operation.

The left kidney was exposed on 18.11.55. (W.B.S.) It was somewhat elongated and projecting from its posterior surface just below the middle was a hard white circumscribed mass identical in size with that shown on the nephrogram.

On section of the kidney no lesion of the upper calyces could be seen. The tumour was white, hard and avascular and appeared to be confined within the limits shown.

Histological examination showed this to be a clear cell parenchymal adenocarcinoma with areas of papillary formation. Pseudo-capsulation was well marked and no evidence of malignancy was found beyond the limits seen on macroscopic examination.

The remarkable difference between the radiological findings was interesting. Whilst it may be said that the pyelographic appearances would have led to exploration and nephrectomy in any case, this does not alter the fact that they were not correct.

No tumour was present anywhere in the region suggested by the pyelograms and the normal appearance of the angiograms in this region was confirmed. The presence and size of the tumour in the lower part of the kidney clearly shown on the nephrogram, were proved to be accurate on pathological examination.

One further type of case must be included as the employment of aortography is vital. This comprises the small cortical neoplasm of a size or position not sufficient to cause any change of the calyceal pattern shown by urography.

Five such instances have been quoted in the literature.

The first, recorded by Nelson (1945) was a man aged 64 who, because of intermittent haematuria, had extensive radiological investigations carried out, all of which showed no evidence of tumour or other abnormality. When eventually aortography was carried out, this showed pooling of the dye in the parenchyma near the periphery of the lower pole of the right kidney. A diagnosis of neoplasm was made and confirmed at operation. The tumour had grown out towards but not

through the capsule.

The second case described by the same author occurred in a man aged 53. This patient had a non-infiltrating tumour of the bladder. Urographic examination was normal but aortography showed bilateral adenocarcinoma of the kidneys.

The third case was that reported by Smith, Rush and Evans (1951) who, in a patient displaying recurrent attacks of haematuria with normal urographic findings, investigated him by aortography.

This showed a small area of pooling and the diagnosis of neoplasm so made was confirmed at operation, a small adenocarcinoma "less than 2 cm. diameter was found immediately beneath the capsule in the area indicated on the arteriogram."

Burns (1953) reported the occurrence of a tumour of 3 cm. diameter not causing any disturbance of the normal pattern of the pyelogram. This tumour was easily diagnosed on aortography by the typical appearance of pooling.

The fifth case was that of a young man described by Harvard (1953). This patient, whilst under investigation for hypertension was shown by aortography to have a small cortical tumour (size not stated) which whilst showing typical pooling had not produced any abnormality on urography.

The following patient may be included in this type of case.

Case (36) D.G. Male aged 64.

History

This patient was seen as an outpatient on 30.7.54. He stated that he had noticed blood in the urine on three occasions within the previous ten days. He had also been aware of some discomfort in the right side. There were no other urinary symptoms and his general health was good.

Urological Investigation.

On clinical examination no abnormality was found in the genito-urinary tract.

Excretion urography was carried out on that date which showed no function of the right kidney, the left being normal. Two days later right ascending pyelography was carried out.

This shows (Fig. 66) that the pelvis is dilated with clubbing of the major calyces. Detail of the minor calyces is lacking. There is the appearance of a "cut-off" at the uretero-pelvic junction.

The right pyelographic appearances whilst not normal are not particularly suggestive of neoplasm.

Aortography was carried out on 24.9.54, the patient having delayed his admission to hospital.

The arteriogram (Fig. 67) shows that there is a double blood supply to each kidney. On the left side the main vessels are separated by the distance of one vertebral body but their distribution and termination are normal. On

the right side the two vessels are much closer together. The supply to the upper half of the kidney is perfectly normal. There are, however, two separate areas of dense pooling in the lower half of the kidney. This appearance is unmistakably that of tumour formation.

It is interesting to note the excellent visualisation of the blood supply to the right adrenal gland. This apparently derives from two vessels arising from the upper renal artery.

The nephrogram (Fig. 68) shows the parenchymal outline and a broadening of the lower pole, the whole kidney being enlarged on the right side. Pooling of the dye is no longer visible on this film. A definite right "adrenogram" is clearly shown.

In view of these angiographic findings removal of the kidney was advised.

Operation

Right nephrectomy was carried out on 5.8.54. (W.B.S.) The double vascular supply was confirmed and each artery separately ligated. The kidney was seen to be enlarged by a firm globular swelling at the lower pole. Examination of the specimen confirmed that it was a fairly well circumscribed tumour, 3.5 cm. diameter, with two vascular sinuses.

Histology confirmed that this was an adenocarcinoma.

This case clearly demonstrates the value of renal angiography in space-occupying lesions of the kidney.

Excretion urography afforded little information and retrograde pyelography did not indicate the presence of tumour with certainty nor did it show the extent of the growth. The arteriogram, apart from affording positive proof of renal neoplasm, portrayed the blood supply. This is of some practical importance as it contributes to the operative technique which in such cases calls for a minimum handling of the kidney.

The nephrogram, it is interesting to see, did not show persistence of the pooling but it did outline the total renal mass.

The last case of adenocarcinoma is that of a patient whose urograms showed no outline of the affected kidney at all.

Case (37) A.G. Male aged 74.

History

This man was sent for examination as an outpatient on 12.11.54. He had suffered from painless haematuria for the previous three weeks. Blood was present in every specimen voided but he had no other urinary symptoms or any other complaint.

Urological Investigation

On clinical examination he was a fit man for his age. No abnormality was detected in the genito-urinary system apart from moderate benign prostatic enlargement.

Cystoscopy showed no abnormality within the bladder but no efflux was noted from the left orifice.

Excretion urography was performed on 16.11.54 and showed the right kidney to be normal in all respects. No dye was seen on the left side.

He returned for ascending pyelography on 23.11.54. No picture of the left kidney was obtained as the ureteric catheter was obstructed at 3 cm. from the bladder orifice and no dye could be made to ascend beyond that point.

He was admitted to hospital and aortography carried out on 29.11.54.

The arteriogram (Fig. 69) shows the right renal blood supply to be normal. On the left side there is a condensation of the dye just beyond the division of the main vessel in an area corresponding to the renal hilum. This appearance is not the typical dense pooling which occurs in a vascular sinus but resembles more an irregular collection of vessels such as angioma. The only other abnormality on the aortogram is the irregular atheromatous appearance of the main vessel, the athero-sclerosis extending into the left main renal artery in the region of the needle.

The nephrogram (Fig. 70) does not clearly define the parenchymal outline which is partly obscured by bowel gas. There is, however, an indeterminate area of increased density at the upper medial part of the kidney. These appearances led to a diagnosis of parenchymal tumour.

Operation.

Left nephrectomy (W.B.S.) was performed on 2.12.54. The kidney which was enlarged contained obvious tumour in the upper medial part. Examination of the specimen showed that it was some 4 cm. in diameter. The bulk of the tumour was relatively avascular but near the centre of it there was an area of lipoid appearance in which many small vessels and sinuses were present. Comparison with the X-Ray films showed that this corresponded to the small area of increased vascularity on the arteriogram - the total tumour mass approximating to the increased density seen on the nephrogram.

In this case a diagnosis of neoplasm was made on the angiograms when urography failed.

It is interesting to compare the findings in this case with those in Cases (40,41)(Figs. 74,75.)

OTHER PARENCHYMAL TUMOURS.

In addition to the cases of adenocarcinoma which have been described, two further examples of solid neoplasm (not carcinoma) were examined. One of these was a fibrosarcoma and the other an adenoma. Both of these tumours are rare and in such cases the diagnosis has in the past only been settled on histological examination.

As will be described, this remains the only sure method of diagnosis and arteriography can not be relied on to produce diagnostic films of such lesions. It can only show the presence of a space-occupying lesion due to tumour formation.

The two cases to be described displayed features worthy of comment.

Case (38) E.M. Female aged 42.

History

This patient was sent for examination on 29.6.54. She complained of flatulence and occasional pain in the right loin which had been present for several months. She had also dysuria and frequency of micturition almost constantly present for four weeks previous to examination. Haematuria had occurred on several occasions for one week.

Urological Investigation.

Clinical examination showed that she was a small slight woman. A mass which was slightly tender was felt in the right loin and hypochondrium. Cystoscopic examination on that date showed some congestion and inflammation of the bladder mucosa but there was no evidence of any tumour formation. The urine was infected with B. Coli.

Excretion urography on 2.7.54 showed the left kidney to be normal but neither the parenchymal outline nor any dye in the collecting system was visible on the right side.

After admission to hospital she was given a course of Sulphatriad to eliminate the urinary infection before proceeding with ascending urography.

This was performed on 9.7.54, the right pyelogram showing one dilated calyx and an incompletely filled pelvis, both displaced and overlying the 11th and 12th ribs. The ureter which was normal in position as far up as the 4th lumbar body then deviated laterally to overlie the tip of the 12th rib.

The presumptive diagnosis was of a large renal tumour although the excessive displacement of the ureter raised the issue of some other retro-peritoneal tumour being present.

Aortography was performed on 14.7.54. This proved to be a difficult puncture and a satisfactory flow of blood

was not obtained. During injection extravasation was suspected and confirmed by the X-Ray film. A second puncture was carried out within three minutes at a lower level.

The arteriogram (Fig. 71) shows extravasation from the higher puncture still present. This does not obscure the left renal blood supply which is normal.

On the right side the renal artery is not hypertrophied but is displaced upwards. The main divisions are also displaced and compressed. The terminal branches are lengthened and run downwards in the lateral part of the mass. Small condensations of dye are present along the course of these vessels. The total vascularity is poor.

The nephrogram was of poor density and showed no pooling but only an indeterminate outline of a large renal swelling.

These appearances proved puzzling and in no way diagnostic. The thinning and displacement of the vessels were more suggestive of hydronephrosis than a solid parenchymal tumour. On the other hand, the considerable prolongation of the terminal branches downwards and the peculiar small condensations of dye along them had not previously been seen in hydronephrosis.

Operation.

Right nephrectomy was carried out on 22.7.54. (A.J.) A large renal mass weighing 1430 gm. was removed.

Secondary malignant deposits were palpable in the liver.

Examination of the specimen showed that renal tissue consisted of a thin rind over the upper part of the mass. This had a somewhat homogeneous whorled, fibrous appearance quite unlike the usual adenocarcinoma. The tumour appeared to be almost avascular.

Histological examination proved the tumour to be a fibro-sarcoma arising from the lower pole.

This patient did not survive and death occurred ten days after aortography. In spite of two punctures and extravasation no evidence of this was found at autopsy.

Case (39) H.L. Female aged 57.

History.

This patient was admitted to the Gynaecological Department on 23.3.54 complaining of right-sided abdominal pain. This had been present for some five years and was in the nature of a dull ache. She had never noticed any blood in the urine nor did she have dysuria, although occasional slight frequency of micturition had been present.

A large firm mass was found on the right side of the abdomen but this was not considered to be of pelvic origin. No gynaecological abnormality was found and she was referred

to the Urological Department on 2.4.54.

Urological Investigation.

Clinical examination showed that she was very stout but a large firm mass was easily palpable in the right abdomen. It was apparently continuous with the kidney above and moved on respiration.

Excretion urography showed poor concentration of the dye on each side and no opinion of the nature of the swelling was possible.

Right retrograde pyelography was carried out on 6.4.54. There was no bladder abnormality. The pyelogram showed the pelvis to be rotated laterally with elongation of the middle and lower calyces. The parenchymal outline was not defined.

A presumptive diagnosis of neoplasm was made.

Aortography was carried out on 9.4.54.

The arteriogram (Fig. 72) shows the left kidney to be normal apart from some deficiency of cortical branching. The right renal artery is hypertrophied, this increase in calibre being prolonged into the two main divisions. The lower of these appears to be displaced upwards towards the renal hilum. The main branches are poor with abrupt terminations and the whole vascularity does not resemble the normal renal pattern. No pooling is present.

The nephrogram clearly indicates the outline of a

grossly enlarged kidney, only the upper part resembling the normal renal shape. An obvious solid tumour is present. There appears to be some slight condensation of the dye in the form of faint circles around the periphery of this lower mass, the centre of which is slightly more translucent. (Fig. 73)

A diagnosis of parenchymal tumour was made but the exact nature of this remained unknown. The absence of marked pooling and the unusual arteriographic outline suggested that this might be an old necrotic avascular adenocarcinoma and such a pre-operative diagnosis was made.

Operation.

Right nephrectomy was performed on 12.4.54. (W.B.S.) A large mass replacing the lower two-thirds of the kidney and corresponding in size to the nephrogram was found. There were no adhesions or fixation of the mass. The blood supply was seen to run to normal-looking renal tissue at the upper part.

On examining the specimen it was found to consist of a pale grey tumour mass with central degeneration. It was quite unlike an adenocarcinoma.

Histological examination showed the tumour to be a simple adenoma. No malignancy was seen in numerous sections taken from different parts of the tumour.

The presence of pooling at any phase in the examination is generally accepted as indicative of an adeno-

carcinoma. The specificity of this, however, is not absolute as is shown by Case (39) in which the tumour was quite simple.

Two other examples in which pooling did not indicate carcinoma have been published.

Dos Santos (1934) described a case in which the arteriographic appearances of bilateral angioma simulated those of adenocarcinoma. The illustration showed a condensation of the dye which could be regarded as pooling, but the arterial pattern was regular with no displacement of the vessels.

The second case was that described by Wagner (1946) in which a lipo-sarcoma which was very vascular showed definite pooling.

Pooling of the dye only occurs in a solid parenchymal tumour and is dependent on the vascularity present. The fact that very occasionally tumours other than adenocarcinoma may show such dye condensation does not detract from the diagnostic value of angiography.

It is not always possible to state at operation the exact nature of the tumour as occurred in the last two cases. Angiography can hardly be expected to diagnose what is only possible on histological examination.

The demonstration of parenchymal tumour is sufficient for practical surgical purposes as this invariably calls for nephrectomy.

OTHER RENAL TUMOURS.

These comprise tumours which affect the collecting system. In practice they consist of transitional cell neoplasms of simple or malignant type and squamous carcinoma. The majority of such growths affect the pelvis rather than the calyces. They are not common and account for only 15% of all renal tumours occurring in the adult.

It is obvious that aortography cannot be expected to demonstrate such renal tumours situated as they are outwith the functioning parenchyma of the kidney. Nevertheless, aortography may prove of value in the investigation of suspected renal tumour by demonstrating that no parenchymal growth is present. Further, it is possible to distinguish between a parenchymal tumour invading the renal pelvis and a pelvic growth invading the parenchyma. (Doss, 1951)

A tumour of the pelvis does not show pooling of the dye. Where extension of such a tumour into the parenchyma occurs the same absence of pooling is a feature of the invaded area. This is relatively avascular and what blood supply it has it derives from that of the original pelvic growth and not from the main renal supply. Thus, the affected parenchymal area far from demonstrating pooling may be rather more translucent than the surrounding normal tissue. This translucency of solid relatively avascular tissue is, however,

not comparable to that of the clear fluid cyst. The arteriogram, apart possibly from some displacement of vessels by the growth, will be normal.

On the other hand, where an adenocarcinoma has invaded the pelvis, pooling of the dye may be present in tumour tissue not only in the substance of the kidney but also within that portion of the growth which has invaded the renal pelvis.

The distinction between these two types of tumour each causing pelvic and calyceal deformity and a pelvic filling defect is by no means easy on ordinary urographic examination.

The practical value of such a distinction when possible lies in the prognosis which is different, of the two types. (Riches, 1951) Further, it is useful in the preparation of the type of operation required, in that ureterectomy should be carried out in the primary pelvic type of tumour. Also, it may influence the use of deep X-Ray therapy should such be contemplated before operation.

The following two cases are examples of tumours of the renal pelvis.

Case (40) J.P. Male aged 76.

History

This man had suffered intermittent pain in the left

loin for one year. In the four weeks before examination he had noticed blood in the urine on five occasions. He was examined in his local hospital where excretion urography failed to outline the left kidney. Three attempts to obtain an ascending urogram had failed. He was admitted to the Urological Department on 15.11.54 for further examination of the upper urinary tract.

Urological Investigation.

Clinical examination showed that he had tenderness in the left loin. The left kidney, however, was not palpably enlarged. No other significant abnormality was found.

Excretion urography was repeated and again showed no function on the left side.

On the following day cystoscopy was carried out, the bladder appearances being normal and the prostate only moderately enlarged. An attempt to obtain a left ascending pyelogram again failed, the catheter being unable to pass up more than a few centimetres.

A presumptive diagnosis of parenchymal neoplasm was made.

Aortography was carried out on 17.11.54.

The arteriogram (Fig. 74) shows the blood supply to the right kidney to be normal, apart from arteriosclerotic changes.

The left renal artery which is normal at the aorta

shows a tapering diminution in its calibre 1 cm. from its origin. Beyond this the vessel and its main branches are considerably thinned.

The usual interlobar branches and their fan-shaped endings are lacking, the appearance being typical of pressure obliteration from hydronephrosis.

The nephrogram (Fig. 75) shows the faint outline of an enlarged kidney of poor vascularity.

On these angiographic appearances a confident opinion was expressed that the kidney was not affected by a parenchymal growth. A diagnosis of hydronephrosis was made but no explanation of the cause could be advanced.

Operation

At operation on 19.11.54 (W.B.S.) the kidney was found to consist of a hydronephrotic sac, the renal pedicle being of small size. The cause of the obstruction was felt to be a tumour within the renal pelvis and the kidney with a long length of ureter was removed.

Histological examination showed that the pelvic growth was a squamous carcinoma.

Case (41) A.N. Male aged 68.

History

This man was first seen as an outpatient on 14.4.52. He had noticed blood in the urine on one occasion five weeks

previously, which had been followed by some discomfort in the right loin. He had no other urinary symptoms.

Urological Investigation.

On clinical examination no abnormality of the genito-urinary tract was found apart from moderate benign prostatic enlargement.

Excretion urography on 14.4.52 showed no excretion on the right side.

Right ascending pyelography was performed on the following day. This showed only some incomplete filling of the renal pelvis - no calyceal outline being obtained. The bladder appearances were normal.

Aortography on 18.4.52 showed results similar to the previous case. It was, however, an early examination and the arteriogram was not of good quality. The lack of definition made it unsuitable for reproduction and it has therefore not been included in the photographs. It was possible on the X-Ray film to make out marked reduction in the size of the renal artery and its main branches. This was considered to represent compression such as is seen in hydronephrosis and to be quite unlike the changes produced by solid parenchymal neoplasm.

Operation.

Right nephrectomy on 21.4.52 (A.J.) confirmed that the kidney was dilated, the obstruction to the urinary outflow being due to a tumour of the renal pelvis.

Histological examination showed this to be a papillary carcinoma of low grade and with no invasion of kidney substance.

SUSPECTED RENAL NEOPLASMS.

The following four cases are included under this heading because on clinical or urographic grounds a renal tumour was suspected. In no case, however, was either a parenchymal or a pelvic neoplasm responsible for the symptomatology.

Case (42) J.B. Male aged 58.

History.

This patient was found to have a small papillary neoplasm of the bladder in 1951. This appeared to be of the relatively benign type and was successfully treated by perurethral diathermy. Subsequent cystoscopic examination at regular intervals showed no recurrence over the next two years. The patient, however, returned in November, 1954, stating that he had noticed further haematuria but had

neglected to report back until then. The bleeding had been intermittent over the previous nine months and more recently had been associated with discomfort in the right loin and hypogastrium.

Urological Investigation.

Cystoscopy on 10.11.54 showed a squat close-packed papillary tumour in the region of the right ureteric orifice which was partly obscured by it. No efflux was seen on that side.

Excretion urography on the same day showed no evidence of dye in the right renal area, the left kidney being apparently normal.

After admission to hospital on 5.1.55 right ascending pyelography was attempted but failed as neither a catheter nor dye could be made to pass up the ureter. No information regarding the state of the right kidney had been elicited by these examinations. Whilst the presence of a parenchymal tumour was unlikely it was not possible to exclude this entirely.

The most obvious explanation was that the kidney was not functioning due to obstruction either from the bladder tumour or from tumour higher in the collecting system of the urinary tract.

Aortography was performed on 7.1.55 to determine the state of the kidney although it was realised that it could not

afford any information regarding the ureter and at best little regarding the pelvis.

The arteriogram (Fig. 76) shows the left renal blood supply to be normal in all respects. The right renal artery is somewhat smaller at its origin and there is a progressive diminution in its calibre as far as its first division. At this point the main artery is very thin and this narrowing is continued along the divisions which are displaced. There is little cortical branching, the total vascularity being poor.

There was no appreciable nephrogram.

These appearances are typical of advanced hydronephrosis. Apart from the bladder lesion, operative treatment was indicated for the kidney.

Operation.

At operation on 11.1.55 (W.B.S.) it was found that renal tissue consisted of a thin rind round a dilated hydronephrotic sac. The vascular pedicle was small. The ureter was dilated and a firm mass was felt at the lower end. The kidney, ureter and a "cuff" of bladder were removed in continuity.

Examination of the specimen showed the mass to consist of hard white tissue 2 cm. in diameter, completely occluding the ureter.

Histological examination proved this and the bladder tumour to be a transitional cell carcinoma.

Case (43) W.P. Male aged 54.

History

This man was sent to the Urological Department on 6.7.54. He had been diagnosed and treated for cystitis two months previously. Haematuria had been profuse on several occasions within the last two weeks. He had still some frequency and discomfort on micturition.

Urological Investigation.

On clinical examination no abnormality was found apart from early benign prostatic enlargement.

Cystoscopy was done, the instrument being passed with some difficulty. Visualisation was poor owing to bladder spasm but it was seen that the margins of the lateral prostatic lobes were inflamed and oedematous.

Excretion urography on 9.7.54 showed poor function on the left side. The calyces were ill-defined but appeared to be somewhat dilated and distorted. The suspicion arose of a parenchymal tumour.

On 13.7.54 cystoscopy was repeated. A blood clot which was present in the bladder could not be evacuated and overlay the left ureteric orifice. This prevented identification and catheterisation of the left ureter.

The appearances of the right side of the bladder were not normal there being marked congestion and swelling of the mucosa in that region. It was not possible to state on

this examination whether this appearance was entirely due to inflammation or to underlying neoplasm.

At this stage in the investigation it was not possible to reach a definite diagnosis. The cystoscopic appearances whilst suggestive of bladder carcinoma did not seem sufficient to account for the degree of bleeding. The presence of clot obscuring the left orifice and the suspicious urographic appearance of the left kidney suggested that the latter might be the site of neoplasm and that the bladder condition was truly inflammatory.

It was decided to investigate further the condition of the left kidney before performing bladder biopsy in the presence of mucosal inflammation.

Accordingly on 27.7.54 aortography was carried out.

The arteriogram (Fig. 6) has already been used to illustrate intra-mural extravasation. The filling of the renal vessels however is adequate for diagnosis. There is no evidence of parenchymal tumour in the form of hypertrophy, displacement or pooling. The left renal blood supply whilst slightly deficient does not indicate hydronephrosis.

The nephrogram showed no significant alteration.

These findings appeared to exclude the presence of renal tumour, particularly of the parenchymal type.

Attention was once more turned to the bladder and further investigation carried out.

Cystoscopic examination was repeated on 12.8.54. On this occasion the mucosal change had advanced and there was no doubt that the condition was one of infiltrating carcinoma.

Further treatment was directed to this.

The use of aortography was justified in this case. In the early stages of the investigation the diagnosis was not clear. The excretion urogram was misleading but did suggest the possibility of renal tumour. Under these circumstances ascending urography being impossible, exploration of the kidney might have been undertaken. Such an unnecessary operation was obviated by the use of angiography.

Case (44) J.M. Male aged 57.

History.

This man was sent to the Urological Department on 22.10.54. He had noticed that the urine had been blood-stained in every specimen passed for the previous three weeks. Although he had an occasional burning sensation on micturition the condition appeared to be essentially one of painless haematuria. He had no other complaints.

Urological Investigation.

On clinical examination the lower pole of the left kidney was palpable and thought to be enlarged.

Cystoscopy yielded a blood-stained urine which

cleared quickly on lavage. There was a definite bloody efflux from the left ureteric orifice.

Excretion urography was carried out on the same day which showed the right kidney to be normal whereas the lower calyces of the left kidney appeared to be elongated and somewhat distorted. It was considered that a renal tumour was the cause of the haematuria.

Left ascending urography was carried out on 3.11.54 the efflux from this side still being blood-stained. The film showed clubbing of all the calyces but with some attenuation of the lower major group.

The suspicion of a neoplasm of the lower pole was raised but the diagnosis was not considered sufficiently definite to warrant immediate operation.

It was decided to repeat the urographic examination in a few weeks time.

Excretion urography was again carried out on 24.11.54. This showed clubbing of the calyces but little detail of the lower major group.

The haematuria which was by now intermittent was nevertheless quite severe at times and he was admitted to hospital.

Aortography was done on 31.1.55 and the arteriogram shows (Fig. 77) that the vascular supply to each kidney is quite normal.

The considerable overlay of the left renal vessel and hilum by the splenic artery does not interfere to any extent with the interpretation.

The nephrogram was so normal that it has been used to illustrate the usual nephrogram effect. (Fig. 2)

The exclusion of a parenchymal lesion in the presence of continued bleeding led to a repeat examination of the collecting system by retrograde catheterisation.

On this occasion, 2.2.55, the urine from the left orifice was again blood-stained. A temporary obstruction to the catheter was encountered 15 cm. from the bladder opening. After overcoming this obstruction, the catheter passed freely to a distance of 25 cm. and clear urine drained from it. The pyelogram showed slight clubbing of the minor calyces.

It was considered that the most likely cause of the bleeding was a primary tumour of the ureter affecting the abdominal portion. It was decided to explore the left ureter and kidney.

Operation.

Exposure of the left ureter was carried out on 8.2.55. (W.B.S.) The kidney and upper ureter appeared to be quite normal but there was a suspicious thickening which affected the pelvic part of the ureter. Under these circumstances nephro-ureterectomy was performed.

Examination of the specimen showed many petechial

spots throughout the mucosa of the lower half of the ureter which also appeared somewhat oedematous. Similar but less marked mucosal changes were present in the renal pelvis.

Histological examination showed no evidence of neoplastic change.

Angiography in this case merely showed the absence of any serious lesion of the renal parenchyma. This was confirmed by pathological examination. Although the instrumental and urographic findings suggested that removal of the right upper urinary tract was reasonable this was in fact proved wrong. Angiography, however, did not contribute to this mistaken diagnosis.

Case (45) D.D. Male aged 55.

History

This man was admitted to the Genito-Urinary Unit, Robroyston Sanatorium as a case of renal tuberculosis on 11.3.55. Haematuria had been present persistently for five days before entering hospital. In addition, he complained of constant dull pain in the right loin which had been present since the bleeding started. He had no increased frequency of micturition and no pain or difficulty in voiding.

There was a past history of pulmonary tuberculosis which had been treated five years previously in Robroyston.

Urological Investigation.

On admission, clinical examination was fairly normal apart from tenderness in the right renal angle. Neither kidney was palpably enlarged. Repeated examinations of the urine including guinea-pig innoculation did not show tubercle bacilli.

Excretion urography on 14.3.55 suggested that the upper major calyx group was dilated and elongated.

Cystoscopy on 22.3.55 showed that the bladder capacity was large with a normal mucosal appearance. The right ureter was catheterised easily and a retrograde pyelogram obtained. This shows (Fig. 78) that the upper major calyx is dilated and lies some distance from the renal pelvis. The neck of this calyx is considerably lengthened but not stenosed. The dye which is fainter than in the remainder of the kidney is continuous throughout the whole length. There is, in addition, compression of the middle calyx from above.

These urographic changes did not suggest tuberculosis and all other tests appeared to confirm this. The possibility of neoplasm had to be considered, especially in view of the compression appearances and the marked haematuria.

The patient was referred on 13.4.55 for renal angiography.

At this time no clinical abnormality could be found, the urine was clear and the patient had no complaint.

The arteriogram (Fig. 79) shows no vascular abnormality suggestive of tumour. The blood supply to the right kidney is rather less than normal. There is some reduction in the size and number of the smaller branches to the upper pole. This was attributed to compression by the dilated upper calyx. The remainder of the right kidney and the left kidney have a normal vascular distribution.

The nephrogram confirmed a slight decrease in vascularity at the upper pole of the right kidney.

A definite opinion was expressed that no tumour of solid renal tissue was present. No operative treatment was advised and the patient was discharged home.

He has remained well and free from pain or haematuria since then - a period of nine months.

SUMMARY AND CONCLUSIONS.

In the eight cases of adenocarcinoma, excretion urography failed to outline the affected kidney except in one case.

Retrograde pyelography was attempted but failed in one case. In the remaining six cases where it was successful it gave a definite diagnosis in three, a suggestive diagnosis

in one, a negative finding in one and a wrong diagnosis regarding the type and location in the last case.

Angiography on the other hand provided a certain diagnosis in every case and in addition accurately assessed the size and location of the tumour.

In the two cases of "Other Parenchymal Tumours" excretion urography showed no function and the retrograde pyelograms were doubtful. Angiography was not definitely diagnostic of the fibro-sarcoma but did demonstrate the size of the adenoma.

Urography gave no satisfactory diagnosis of the two cases of squamous carcinoma of the renal pelvis whilst angiography excluded a parenchymal neoplasm.

In the four cases of suspected renal tumour such a diagnosis was disproved by angiography whilst a similar exclusion was shown in the remaining case in which urography failed to outline the affected kidney.

The diagnostic appearances of angiography in renal adenocarcinoma consist of hypertrophy of the nutrient vessels and pooling of the dye. The nephrogram will indicate the size and position of the growth.

Angiography will demonstrate any tumour obvious on urography. It will also demonstrate tumours not shown on urography because no pyelographic deformity is present.

It will preclude parenchymal neoplasm where the

urographic findings are equivocal.

It will provide a surer distinction between solid tumour and cyst than urography.

It will not demonstrate tumours confined to the collecting system.

UNILATERAL RENAL BLEEDING.

The vast majority of conditions producing bleeding from one kidney, with or without other associated symptoms, can confidently be diagnosed by the usual urological methods. The commonest lesions in the kidney responsible for bleeding consist of neoplasm, calculus disease, tuberculosis, infection and hydronephrosis.

There remains one group in which renal bleeding occurs without obvious cause and to this the unfortunate term "essential haematuria" has been applied. Many urologists deny the existence of such a condition claiming that the acceptance of such a diagnosis constitutes a confession of failure to elucidate the cause of the bleeding.

Nevertheless, whilst such cases are uncommon, they do occur and show no urographic abnormality even where on cystoscopy there is profuse haematuria from one ureteric orifice.

Where nephrectomy is carried out, many such kidneys show little pathological abnormality even on histological examination, beyond vascular congestion or small areas of focal nephritis. Occasionally such a kidney may show small varices or minute angiomata.

The management of renal haematuria in which the urographic findings are quite normal may present difficulties and anxieties. It is not always easy to state with assurance that the condition is trivial - there remains the suspicion and possibility of a serious lesion such as tumour. It has already been shown that small cortical tumours may be present without any pyelographic deformity. Delay or procrastination in such cases may literally prove fatal.

Whilst repeated urographic examinations which appear normal and the exclusion of any infective element suggest that the lesion is not serious, the problem of surgical intervention may arise when the haematuria is persistent or intermittently profuse.

Surgical exploration usually means nephrectomy. Inspection of the external surface of a kidney exposed at operation may afford additional information regarding the

presence of a lesion but this is seldom the case. The only other means of determining the presence of any abnormality is to open the kidney by splitting it in the sagittal plane from the convex border to the hilum. This also seldom yields further information.

In such an event, the decision has to be made whether, having explored the kidney and found nothing pathological, the organ should or should not be removed. Certainly nephrectomy will stop the bleeding but it is questionable if the removal of such a kidney is always justifiable or necessary. On the other hand, to suture and conserve the kidney does not exclude the possibility of a serious lesion and may not result in the arrest of haematuria even when decapsulation is performed.

Thus in the majority of cases in which exploratory operation is carried out, the kidney is usually removed.

Where bleeding persists from one kidney and the urographic appearances are repeatedly normal, renal arteriography should be carried out.

In the discussion of the interpretation of the renal angiogram, it was stated that any alteration in the normal vascular pattern denoted some abnormality in the parenchyma of the kidney. The converse is also true - where the angiograms are absolutely normal no serious lesion of the parenchyma can exist.

In such cases the indications for exploratory

operation are fewer. This does not imply that operation will never be necessary for such renal bleeding - this may be so severe as to endanger life. In such an unlikely event nephrectomy may be necessary and justified.

Whilst nephrectomy will stop the bleeding many of these cases, whether due to focal nephritis or varices, will cease bleeding in time. Surgical intervention may be withheld more confidently when, in addition to urography, the angiographic appearances are normal. This accords with the views of Melick and Vitt. (1948)

Renal angiography has been employed in the investigation of seven patients who may be regarded as falling into the category of "essential haematuria". Nephrectomy was carried out on two of these patients.

Case (46) A.C. Female aged 36.

History

This woman was first seen as an outpatient on 22.1.54. She had suffered intermittent attacks of haematuria during the preceding ten months. She had no pain and no other urinary symptoms. She had no previous illnesses and felt well.

Urological Investigation.

On clinical examination, no abnormality was found

and she appeared to be a healthy young woman.

Cystoscopy yielded a blood-stained urine but examination showed no pathological change in the bladder.

The urine from the right ureter was blood-stained.

Excretion urography on the same day showed good function of both kidneys, the outline of which appeared to be quite normal.

Right ascending pyelography on 29.1.54 again confirmed bleeding from the right side but apart from some fullness of the renal pelvis the appearances were normal.

Culture of the urine showed a growth of B. Coli for which Sulphonamide therapy was prescribed.

No blood dyscrasia was found. The blood pressure was normal.

The haematuria persisted and she was admitted to hospital for further examination.

Aortography was performed on 19.2.54.

The arteriogram (Fig. 80) shows a normal vascular distribution within each kidney.

The right renal artery is longer than normal and the kidney somewhat ptosed.

The nephrogram showed an even density throughout each kidney.

In view of these normal angiographic findings it was considered that no serious parenchymal lesion could be

responsible for the bleeding and operative intervention was not recommended.

The patient was discharged home and was advised to continue with a copious fluid intake.

She reported a month later still having fairly frequent haematuria.

Cystoscopy on 19.3.54 again showed this to come from the right orifice.

She was seen a month after that, the haematuria still being persistent.

In view of this she was re-admitted to hospital on 10.5.54.

Operation.

Right nephrectomy was performed on 11.5.54. (A.J.) At operation no pathological change of the kidney was seen.

Histological examination showed a mild degree of ureteritis cystica with Brunn's nests in the wall of the ureter. Within the parenchyma a few tiny pyelonephritic lesions were seen.

Case (47) A.G. Male aged 54.

History

This man was first seen on 13.5.52. He stated that he had noticed blood in the urine at intervals over the previous twenty-one months. He had no frequency or pain on

micturition. He had experienced some discomfort in the right side especially in the iliac fossa. This had been present for some weeks before examination. He had no other complaint and felt quite well.

Urological Investigation.

Clinical examination was essentially normal. Cystoscopy was performed, the only abnormality being a blood-stained urinary efflux from the left ureteric orifice.

Excretion urography was carried out on the same day and showed the calyceal pattern of each kidney to be normal. The upper part of the right ureter appeared to be slightly dilated.

He returned for further examination and left retrograde pyelography on 16.5.52 was normal.

No operative treatment was advised but he was asked to report back.

On 29.5.52, following a recurrence of bleeding, bilateral ascending urography was done and showed both kidneys to be normal.

He reported back on 1.8.52 following a return of haematuria.

Excretion urography was repeated, the appearances being apparently normal.

Blood continued to appear in the urine at intervals over the next two months and he was admitted to hospital.

No blood dyscrasia was found. There was no hypertension.

Bilateral ascending urograms again showed no pathological change in the kidneys.

Aortography was carried out on 16.10.52.

The arteriogram showed a normal blood supply to each kidney. The nephrogram also failed to show any abnormality. These have not been included in the illustrations as the detail is faint, this being an early case in which hand pressure and a stationary grid were used.

It was considered, however, that the detail was sufficient to exclude a serious parenchymal condition.

Operation.

The left kidney was explored on 20.10.52. (A.J.) No gross pathological change was seen but in view of the continued bleeding the kidney was removed.

Histological examination showed scattered areas of focal chronic pyelonephritis. No other source of haemorrhage could be identified.

These two cases proved to be interesting and instructive. In neither case was any abnormality seen on the urograms and the absence of any significant pathological change in the parenchyma was shown by the angiograms. Subsequent histological examination confirmed these findings.

The following five cases did not have operation performed.

Case (48) E.A. Female aged 67.

History

This patient was seen on 17.1.55 complaining of blood in the urine. The haematuria had been present continuously for two weeks and was associated with slight frequency of micturition. She had no pain and no other complaint. She stated that six months previously she had noted that the urine was blood-stained over a period of ten days. She had been treated for cystitis sixteen years ago and passed a stone eight years previously.

Urological Investigation.

On clinical examination slight tenderness was elicited in the left loin. Neither kidney was palpable but the patient was very stout.

Cystoscopy on 17.1.55 yielded a blood-stained urine which cleared rapidly on lavage. The bladder appeared to be normal but a blood-stained efflux was seen to come from the left ureteric orifice.

She returned two days later for excretion urography which showed no opaque calculus in the urinary tract. The dye concentration was not very good but there appeared to be a tendency to a bifid pelvis on the left side.

This required further examination and ascending urography was performed on 21.1.55. This confirmed the previous findings of a bifid pelvis. There was dilatation of the lower major pelvis and clubbing of the minor calyces. On this occasion a blood-stained efflux was still present.

Urine examination showed a mild infection due to B. Coli for which Sulphatriad was administered.

In view of the age of the patient and the continued haematuria, the possibility of renal tumour could not be excluded.

No blood dyscrasia or hypertension was present.

It was decided to perform aortography combined with pre-sacral air insufflation to the left side.

This was carried out on 24.1.55, aortic puncture being done five minutes after air injection under general anaesthesia.

The arteriogram (Fig. 81) shows a double blood supply to each kidney.

The total vascularity of the affected left side is rather less than the right which is normal. The main branches are thin and the cortical supply is poor. There is nothing suggestive of parenchymal tumour in the form of pooling or increased vascularity to any area. The kidney outline is shown by the surrounding air.

The nephrogram appeared to be normal.

After three days treatment with Sulphatriad the haematuria ceased and the frequency of micturition became less severe. The exclusion of a solid tumour was accepted but a further instrumental examination was done on 26.1.55.

The efflux from the left side was now clear and a retrograde pyelogram again showed some dilatation of the calyces and lower pelvis. This was not considered to be serious and the patient was discharged from hospital a week later quite free from symptoms.

There has been no recurrence of haematuria or urinary frequency since then - a period of one year.

Case (49) A.S. Male aged 38.

History

This man was referred for examination on 19.2.54 having had painless haematuria. The bleeding had been persistent for the previous three days but two weeks before that had been present for six days. He had no other complaint and had no pain or difficulty on voiding urine.

Urological Investigation.

Clinical examination showed him to be a healthy man and no abnormality was found.

Cystoscopy confirmed that blood was present in the urine but the bladder appearances were normal. The efflux from the left orifice was deeply blood-stained.

The urine did not show any organisms on direct examination or culture.

Excretion urography on the same day (Fig. 82) shows no opaque calculus. The concentration of the dye is good and both kidneys appear normal apart from a lengthened neck of the upper calyx on each side. On the left side there is a "cut-off" at the uretero-pelvic junction. There is some expansion of the ureter for a short distance below this but the pelvis and calyces are not dilated.

Left ascending pyelography was done on 26.2.54.

The haematuria had lessened in the interval and was now intermittent but was still present at this examination. No abnormality was seen in the left urinary tract. The constriction at the uretero-pelvic junction was not seen as a result of the catheter having passed beyond it to lie within the renal pelvis.

No specific treatment other than copious fluids was advised.

The patient remained well and free from haematuria for two months.

Following a further episode of transient bleeding he was admitted to hospital for aortography which was done on 7.5.54.

The arteriogram (Fig. 83) shows a good normal blood supply to each kidney.

The definition is clearer on the right side due to the position of the needle point which lies nearer to the origin of the right renal artery than the left. The vascular distribution within each kidney is normal and there is nothing suggestive of neoplasm.

Comparison of the left angiogram with the urogram suggests that the "cut-off" may be due to pressure from a vessel. The main branch to the lower pole arises well clear of the kidney and in its course downwards crosses the ureteropelvic junction.

The nephrogram showed no abnormality.

The patient was discharged from hospital and examined as an outpatient on 2.7.54. There had been no recurrence of haematuria and excretion urography again showed no significant abnormality. The appearance of constriction was less marked and there was no dilatation.

The patient has remained well and free from bleeding for the past eighteen months.

Case (50) T.D. Male aged 50.

History

This man was first seen as an outpatient on 9.10.53 complaining of blood in the urine. The haematuria was quite painless and had been present intermittently for four weeks. He had no other complaint and felt well.

Urological Investigation.

Clinical examination was essentially normal.

Cystoscopy was performed and showed no intrinsic bladder lesion. There was a deeply blood-stained urine from the right ureteric opening.

Excretion urography on 12.10.53 was normal in all respects.

The following day cystoscopy was repeated with similar results and the right ureter was catheterised.

The ascending pyelogram showed no abnormality.

Blood examination was normal and he had no hypertension.

The patient was advised to take copious fluids and to report again in two weeks.

On 27.10.53 he had a repeat excretion urogram performed as bleeding had continued intermittently during the interval. This urogram again appeared to be normal.

He reported again on 1.12.53 and stated that blood was still present although the quantity was less and the intervals between attacks much longer. Excretion urography with compression appeared as before to be quite normal.

In view of the continued presence of haematuria he was admitted to hospital on 22.1.54 for angiography.

The arteriogram and nephrogram showed no abnormality of either kidney. This examination was performed under local

anaesthesia and during injection of the dye slight involuntary movement occurred. This resulted in some lack of definition which renders the angiograms unsuitable for reproduction.

The result of this examination in conjunction with the repeated normal urographic findings confirmed the decision that operation should not be performed.

The patient was seen at intervals over the next six months during which he had transient haematuria on several occasions.

Following fairly profuse haematuria lasting three days he was admitted again to hospital on 10.7.54. The bleeding ceased and the urine remained clear for a week and he was therefore discharged home, a further urogram having shown no abnormality.

Blood again appeared in the urine on 10.9.54 but has not recurred since then.

He has been quite free from haematuria for the past fifteen months.

Case (51) A.H. Male aged 73.

History

This man was sent for examination on 11.4.52 having had blood in the urine for three days. The haematuria had occurred suddenly but had persisted. He had no pain but slight frequency of micturition. He had no other complaint

and felt well.

Urological Investigation.

Clinical examination showed him to be a well-preserved man for his years. Apart from moderate benign prostatic enlargement no abnormality was found.

Cystoscopy confirmed the presence of blood in the urine. The bladder appearances were fairly normal and prostatic intrusion was not marked. The urine from the right orifice was blood-stained.

Excretion urography on the same day showed the left kidney to be normal but dye concentration was poor on the right side and no detail could be made out.

He was advised to take copious fluids and report back.

He returned on 21.4.52, the urine having remained clear in the interval.

Right ascending pyelography showed clubbing of the calyces and slight dilatation of the renal pelvis.

No serious lesion was considered to be present in the kidneys and he was advised to report in the event of further haematuria.

He had a further attack of bleeding two weeks later and was admitted to hospital for further examination.

Aortography was performed on 8.2.52.

The arteriogram and nephrogram showed no alteration in the vascular pattern or functioning parenchyma suggestive

of neoplasm. (These films are not illustrated.)

The haematuria which ceased just before admission did not recur and the patient was discharged home. There has been no recurrence of blood in the urine since then - a period of three years.

Case (52) T.M. Male aged 28.

History

This man was sent for examination on 19.10.54. He had suffered intermittent attacks of painless haematuria for the previous seven weeks. The bleeding had been profuse at times and usually lasted for some four to five days.

Urological Investigation.

No abnormality was found on clinical examination. Cystoscopy yielded a blood-stained urine which cleared rapidly on lavage. The bladder appearances were normal and a clear efflux was seen to come from the orifice of the right ureter. No efflux was noted from the left side.

Excretion urography on 22.10.54 showed the right kidney to be normal but the left side was not properly delineated.

Cystoscopy was repeated on 26.10.54, the urine still being blood-stained. On this occasion it was seen to come from the left ureteric orifice. Ascending pyelography on this side showed some clubbing of the calyces of the lower pole.

In view of the persistence of bleeding he was admitted to hospital and aortography performed on 26.11.54.

The arteriogram (Fig. 84) shows some reduction in the size of the left renal vessels but no other significant abnormality may be seen.

The nephrogram was normal on each side.

In view of these findings it was considered that no serious parenchymal lesion was present and no operative treatment was advised.

The haematuria persisted from the left kidney and ascending pyelography was repeated on 15.12.54. This again showed only slight clubbing of the lower left calyces.

The subsequent progress of this patient has been satisfactory, the bleeding gradually lessening over the next six months. He was last seen on 24.10.55 having been free from haematuria for a period of six months.

CONCLUSIONS.

The findings in these patients support the contention that angiography is of value in the management of unilateral renal bleeding.

In the two patients (Cases 46, 47) on whom

nephrectomy was performed, the only pathological finding as is usual in such cases, consisted of small focal areas of infection. It is not improbable that haematuria would have ceased in time. Such was the case in the five patients on whom no operation was performed.

A follow-up of these suggests that such a conservative treatment was justified.

It may be said that such a policy could have been carried out equally well without recourse to aortography. It is felt that this is not entirely true.

In cases (48, 51) the age of the patients and the minor changes in the urograms could not exclude a suspicion of neoplasm. The angiograms, however, provided confirmatory evidence that no serious parenchymal lesion was responsible for the bleeding.

Case (50) illustrates very well the increased confidence engendered by the finding of a normal vascular supply. In spite of prolonged and at times profuse bleeding surgical intervention, which could only mean the removal of the kidney, was withheld. It is doubtful if on the urographic appearances alone such advice would have been given.

In the same way Cases (49, 52) were treated expectantly and no anxiety felt regarding such a policy.

The information to be gained by angiography in unilateral renal bleeding of unknown cause is useful in two ways:-

(1) It may reveal the cause and source of the bleeding when urography fails to do so.

(2) It may offer surer evidence that no serious lesion of the renal parenchyma is present.

This assurance is of even greater value when disease affects the other kidney.

AORTOGRAPHY IN DIAGNOSIS

VOLUME TWO

C O N T E N T S

VOLUME II

HYDRONEPHROSIS.

It is beyond the scope of this thesis to discuss all the causes of hydronephrosis. Frequently, however, obstruction to the outflow of urine from the kidney is due to a lesion affecting the uretero-pelvic junction. Thus, apart from the presence of calculus it may result from ureteric stenosis, accessory or aberrant vessels, fibrotic bands, malrotation of the kidney or a high insertion of the ureter.

The successful management of a case of uretero-pelvic obstruction causing hydronephrosis is one of the most satisfying aspects of urological surgery. This entails a conservative operation such as plastic repair rather than nephrectomy. The decision whether to conserve or remove a hydronephrotic kidney is important but it is not always an easy one.

Nothing will be gained by performing a plastic operation unless adequate renal function is present in the affected kidney. Should nephrectomy be performed, the development of disease in the remaining kidney may be very serious. Apart from some other disease, it is not sufficiently realised that uretero-pelvic obstruction, though usually unilateral when first discovered, may actually or potentially be bilateral.

Following nephrectomy there is a physiological

hypertrophy of the remaining kidney. This enlargement of the kidney may in certain circumstances initiate or accelerate the development of hydronephrosis in the remaining kidney.

It is therefore desirable to preserve whenever possible a kidney damaged by such obstruction rather than to remove it.

There is still considerable conjecture about the relationship between accessory or aberrant vessels and hydronephrosis.

By many it is felt that this relationship is too frequent to be entirely fortuitous.

Anderson (1953) found that in 72 patients with hydronephrosis, accessory vessels were present at operation in 40 of them. In 26 of the 40 he considered that the accessory vessel was directly responsible for the obstruction. In the remaining 14 he considered it to be a contributory factor.

On the other hand, many surgeons feel that such vessels are not the initial cause of the obstruction.

Accessory vessels are of congenital origin, yet in an examination of 828 children up to the age of 15 with hydronephrosis, Meredith Campbell (1951) considered that in only 37 cases were such vessels responsible for the obstruction.

Whether or not such vessels are directly responsible

for the initial obstruction it is generally accepted that the subsequent course of events is as follows.

Any accessory vessel or band of tissue has a relatively fixed position in relation to the uretero-pelvic junction. If there is obstruction or in the case of the remaining kidney, enlargement, there is involvement of the pelvis with this fixed structure. This leads to greater effort and less efficient emptying.

Thus there is delay in emptying, hypertrophy, more delay, more obstruction and eventually dilatation leading to prolapse of the pelvis over the obstruction. If this is not relieved in time the end result is renal decompensation and destruction.

In the investigation of suspected hydronephrosis two main points have to be determined - the degree and type of dilatation and the renal function. These two factors are to a large extent interdependent.

Excretion urography remains the commonest and easiest method, in that the diagnosis may be confirmed radiologically by the anatomical outline of the pelvis and calyces and the function measured by the density and time of appearance of the dye.

Where a satisfactory anatomical outline appears it usually follows that satisfactory function is present. In such cases - almost invariably of minor intra-renal

hydronephrosis - no further investigation of function may be necessary.

In the more advanced case there is inevitably some interference with function and this, in conjunction with the dilution of the dye in the urine in the dilated collecting system, frequently results in unsatisfactory urograms. In many cases no dye at all can be seen. In either event, care must be taken in the interpretation of such results which do not necessarily imply considerable loss of function, either transient or permanent. That adequate function exists may be proved by the finding of a good renal parenchyma at operation and satisfactory excretion urograms following plastic repair.

One further factor is the effect of pain due to distension. It is well recognised that following an attack of renal colic or severe pain excretion urography fails to outline the affected kidney. In the majority of cases this loss of function is transient and recovers quickly. In established hydronephrosis, with or without pain, it is by no means possible to determine in every case whether this loss of function on excretion urography is transient or permanent.

In most urological clinics it is the practice to carry out ascending urography in order to demonstrate the detail of the pelvic and calyceal outline. This is almost invariably obtained and where no information has been elicited

on excretion urography is an obvious valuable procedure.

There is some disagreement, however, about how and when such instrumental examination should be done. On the one hand there are those who maintain that, following ascending urography, the catheter should be left in situ so that the dye and urine may be effectively emptied from the pelvis by continuous drainage.

On the other hand there are those who feel that the catheter should be withdrawn immediately after injection of the dye. Only in this way, do they contend, may the emptying capacity and degree of obstruction be judged by subsequent radiological examination at regular intervals.

Whatever method be used, it cannot be denied that on occasion an acute crisis may be precipitated. The passage of an ureteral catheter and the injection of the medium may result in a bacterial or chemical inflammation. In either case infection or oedema may be promoted, leading to further obstruction. The existence of previous infection only means that the kidney, though tolerant to existing infection, is probably less able to withstand the insult of fresh contaminants.

Modern surgical precautions, the use of antibiotics and sulphonamides and an experienced operative technique all contribute to making such a mishap a rare and usually unimportant event.

Nevertheless, every urologist is aware of cases in which a serious acute crisis occurred following ascending urography.

One recent personal experience may be quoted briefly.

A young medical colleague was suspected of having unilateral hydronephrosis. A left ascending urogram was carried out, particular precautions being taken in this case. The result showed a well-marked extra-renal hydronephrosis for which plastic repair seemed very suitable.

Acute obstruction and infection developed, the latter not responding to antibiotic therapy. The condition progressed to pyelonephritis and cortical abscess formation requiring nephrectomy. Thus, a kidney which might well have been conserved, was removed as a result of ascending urography. Fortunately the remaining kidney was normal but had it been diseased or absent the result would have been tragic.

Whilst ascending urography will give the maximum detail regarding the anatomical outline of the collecting system it can afford no information whatsoever regarding renal function.

The other methods which may be employed to determine this include chromocystoscopy and biochemical estimations of separate specimens of urine from each kidney.

These separate renal tests, especially those obtained by ureteral catheterisation have in my experience

frequently proved unreliable if not misleading. Where the usual type of ureteric catheter is used there is an inevitable "spill" past them which renders excretion tests invalid. If a "Foley" type is used the distension of the bag, with or without the production of pain, may produce reflex spasm and similarly affect the results.

At best such tests are rather crude and, whilst results showing satisfactory function may be reassuring, a poor result is not necessarily a true one. A total biochemical estimation of renal function is of little value in assessing the operative procedure to be adopted for one kidney.

There are two main contributions which angiography will make in the investigation of hydronephrosis.

The arteriogram will determine the presence or absence of accessory vessels. The demonstration of an accessory or aberrant artery on the affected side does not necessarily imply that it is a direct factor in the condition. The superimposition of the arteriogram on the urogram will, however, usually demonstrate the relation of such a vessel to the pelvis and uretero-pelvic junction. The extent of renal parenchyma supplied by an accessory vessel will be shown. This is of practical importance should ligation of the vessel be contemplated at operation. Although the demonstration of an accessory vessel is dependent on its patency its presence may be adduced even when it is obliterated by a stump at its

origin and an ischaemic area in the part of the kidney supplied by it.

The arteriogram will also demonstrate the presence of a similar anomaly on the other side. This may be of importance in the prognosis and subsequent treatment of the patient.

The second and most valuable piece of information afforded by angiography is in the assessment of renal function. Doss is the originator of the statement that "A kidney is no better than its blood supply." My experience of renal angiography is in entire agreement with this and more recently Riches (1955) has gone so far as to state "We have come to regard renal angiography as an essential investigation in all cases of hydronephrosis".

The development of hydronephrosis is associated with a progressive dilatation of the calyceal system which in turn leads to compression of normal parenchymal tissue. Within this tissue lies an extensive vascular supply which is also obliterated. In the advanced case only a thin rind of cortex may remain. In such kidneys it is probable that the vascular supply provides little more than viability of the remaining tissue and no excretory function.

The degree of obliterated renal tissue is reflected in and may be judged by the vascular pattern as shown on arteriography.

Cortical atrophy and therefore reduction in the peripheral vascular bed shows as a reduction in the size and number of the renal arterial branches. The typical fan-shaped endings disappear whilst the larger proximal branches become thinned and displaced around the dilated calyces. In extreme cases the main extra-renal branches become reduced in size and may even become obliterated. Where this occurs in the renal artery itself the stump of origin from the aorta remains visible and serves to distinguish the non-functioning avascular kidney from the absent one.

The nephrogram will provide even more valuable information. It will show the size and outline of the kidney and permit comparison to be made with the urogram regarding the anatomical position of the dilated pelvis and calyces. More important, being a measure of capillary vascularity and early tubular concentration it is a reliable guide to actual function.

None of the other methods of investigation can provide any information regarding potential function where the actual function at the time of the test is poor.

Reference has been made to the effect of renal pain on excretion urography. If the mechanism, presumably of neurogenic origin in analagous to the "Trueta Shunt" there is a temporary shut-down in cortical activity. Such a reaction however, should not affect to a marked degree the major blood supply to the kidney. If arteriography shows the latter to be

good the potential activity of the kidney will also be good.

In the same connection, angiography may prove valuable where the kidney is totally obstructed. Whilst animal experiments suggest that six weeks is the maximum time within which recovery of function can take place in the dog, the limit beyond which a human kidney cannot recover is not known.

Thus angiography can play an important part in the management of hydronephrosis. Where an adequate vascularity is present a conservative treatment may be adopted. Where vascularity is very poor, nephrectomy will be necessary.

At once the point arises; what degree of vascularity is consistent with adequate renal function? This question cannot yet be answered. In practice it has been found that when 30% of the normal arterial supply is shown and the nephrogram suggests 30% of the normal density, conservation of the kidney should be attempted.

This assessment, it is admitted, is arbitrary and may require revision in the light of experience. Nevertheless, it is felt that angiography offers a truer appreciation of actual and potential function than any other method.

In this series 26 cases of hydronephrosis have been investigated. They have been divided into four groups.

(1) Minor hydronephrosis for which operation was not necessary.

(2) Advanced hydronephrosis requiring nephrectomy.

(3) Hydronephrosis secondary to tumour or obstruction not at the uretero-pelvic junction.

(4) Hydronephrosis suitable for plastic resection.

In the first group four cases were considered to be of the minor type.

Case (53) R.M. Male aged 52.

History

This patient was referred for urological examination on 9.11.54. He complained of pain in the right side which had been present constantly for five weeks. At first the pain had been very severe in the loin and was associated with dysuria and frequency of micturition. His doctor found that the urine contained pus cells and considered the condition to be pyelitis. In spite of treatment with Sulphadimidine and Chloromycetin the pain persisted although it was less severe.

Urological Investigation.

On clinical examination he was a well-built healthy looking man. The right kidney was palpable and slightly tender.

The urine was clear and contained no abnormal constituents.

Excretion urography on 12.11.54 shows (Fig. 85) moderate dilatation affecting the calyces and pelvis of the right kidney. The left kidney is normal although there is a tendency to some fullness of the renal pelvis.

Cystoscopy one week later was quite normal and a right pyelogram (Fig. 86) confirmed that there was moderate hydronephrosis. The pelvis is dilated but its relation to the kidney is not clear as no parenchymal outline can be made out. The possibility of plastic operation was considered and he was admitted later to hospital for further investigation and treatment.

Aortography was performed on 31.1.55. This patient was a subject of one of the pressure experiments in which two needles were inserted into the aorta.

The arteriogram (Fig. 87) shows that each kidney has a double blood supply. On the affected side the upper major right renal artery divides close to the aorta and these two divisions, along with the lower artery run out close to each other to give a good blood supply to the kidney.

Comparison with the urograms suggests that none of these vessels can be an obstructive factor as they lie well above the uretero-pelvic junction. In the same way the left renal arteries are not considered responsible for the slight pelvic fullness.

The nephrogram (Fig. 88) shows that the outline and

density of the right kidney are normal and in fact the function is superior to that of the left kidney.

In view of these findings it was decided to employ Pituitrin therapy rather than operation to effect a reduction in the dilatation of the pelvis and calyces.

Pituitrin 0.5 ml. daily was given for two weeks followed by 0.5 ml. every alternate day for one week.

Excretion urography on 2.3.55 shows (Fig. 89) considerable reduction in the dilatation, especially of the calyces which have recovered their normal cup-shaped appearance.

Case (54) M.M. Female aged 38.

History

This patient was referred for examination of the urinary tract on 8.2.54 with the following history. Three years previously the right kidney had been removed in another hospital for gross hydronephrosis. A copy of the operation notes stated that "an aberrant vessel was present and was considered to have been the cause of the obstruction."

Since then she had suffered intermittent attacks of pain in the left loin sometimes associated with frequency of micturition and fever.

Urological Investigation.

On clinical examination no significant abnormality was found except that the left kidney was palpable. There was

no tenderness.

The urine examination was normal.

Excretion urography showed good concentration of dye in the remaining left kidney.

The pelvis was not dilated but there appeared to be a "shut-off" from the ureter which was not seen below this.

In view of these appearances it was decided to investigate the condition of the left kidney in more detail.

On 11.2.54 a combined aortogram and retrograde pyelogram was carried out under general anaesthesia.

The bladder appearances were normal and the left ureter was catheterised easily. Injection of dye was made after aortic puncture and a combined picture obtained.

The arteriogram (Fig. 90) shows a good normal left renal artery. In addition there is a small accessory vessel which arises one vertebral body lower and crosses the ureter just below the uretero-pelvic junction. The stump of the right renal artery is shown.

The pyelogram shows no dilatation of the pelvis or calyces.

In this case the ureteric catheter was left in position so that the relationship of the vessels to the ureter could be seen with certainty. This, however, does not permit the demonstration of constriction by a vessel and it might be preferable to carry out such a combined examination with the

catheter withdrawn below the suspected level of ureteric obstruction.

The good blood supply and functioning parenchyma and the absence of dilatation although an accessory vessel was present did not indicate the need for any specific treatment.

This patient has remained well since but it is felt that excretion urography should be carried out at regular intervals in case there should be a symptomless dilatation of the remaining kidney.

Case (55) M.H. Female aged 21.

History

This young woman was referred for examination on 9.11.53. Two months previously she had been admitted to a General Surgical Unit following an attack of right renal colic. X-Ray showed no opaque calculus. Although there had been no recurrence of colic she still had attacks of intermittent pain in the right loin.

Urological Investigation.

Clinical examination was normal and the urine contained no unusual constituents.

Excretion urography showed slight dilatation of the right renal pelvis.

Cystoscopy on 13.11.53 showed normal bladder appearances and a right ascending pyelogram showed early

hydronephrosis with clubbing of the calyces.

Aortography was performed on 14.12.53 and showed no vascular abnormality and good functioning renal parenchyma.

After treatment with Pituitrin 0.5 ml. daily for a week a repeat excretion urogram showed reduction in the pelvic dilatation.

The patient has remained free from pain since then.

Case (56) W.S. Male aged 59.

History

This man was referred for urological examination on 2.10.53 having had an attack of left renal colic two days previously.

Urological Investigation.

No clinical abnormality was found.

Excretion urography showed some minor dilatation of the left renal pelvis and calyces.

This was confirmed by ascending pyelography the following day.

Aortography was carried out on 7.10.53 and showed no abnormality on the arteriogram or nephrogram. No accessory vessel was present.

No operative treatment was necessary.

Excretion urography performed four weeks later showed some resolution of the dilatation.

In three of these four patients minor hydronephrosis only was present. In none of these was the dilatation - which was reversible - sufficient to cause any angiographic change. The actual and potential function of the affected kidney was normal.

In the fourth patient (Case 53) the remaining kidney did not show any pelvic or calyceal dilatation although it was enlarged and an accessory vessel was present.

The accessory vessel in Case (50) was not considered to be the causal factor in the dilatation.

In the remaining two cases, not illustrated because the angiographic appearances were quite normal, accessory vessels were not present.

Aortography was carried out in these cases to confirm the close relationship between vascularity and function and to prove that it may be demonstrated clearly by this method of examination; also to show any accessory or aberrant arteries and their relationship to the site of obstruction.

The second group consists of those patients in whom the dilatation had progressed to such a degree that nephrectomy was necessary. There were five patients in this group in all of whom operation was performed, except one (Case 57) in whom the condition was bilateral.

Case (57) J.K. Male aged 66.

History.

This patient was referred for examination of the urinary tract on 2.7.52. He complained of back-ache which had been present for several years. The pain was worse on the right side but he had also some discomfort on the left side. He had occasional frequency of micturition.

Urological Investigation.

Clinical examination yielded no significant abnormality.

Excretion urography showed very faint evidence of dye in each kidney but no opinion could be given on these films.

Cystoscopy on 5.7.52 showed moderate intra-vesical intrusion of the prostate but the bladder appearances were otherwise normal.

The urine was not infected.

Bilateral ascending pyelograms were not successful the dye failing to outline either kidney.

A further attempt at instrumental examination of the right kidney on 17.2.52 shows (Fig. 91) marked hydronephrosis of the right kidney.

Aortography was performed on 29.5.52, using a No. 18 S.W.G. needle and hand pressure.

The arteriogram (Fig. 92) which is of poor quality shows the right renal artery to be small. The main divisions

are thin, displaced and lengthened. The total vascularity is poor and the cortical supply is almost absent. The left renal artery arises much lower and is partly obscured by the superior mesenteric vessel but there is obvious poor vascularity to the left kidney.

A diagnosis of bilateral hydronephrosis with poor renal function was made.

No operative treatment was recommended and the patient was discharged home. No further information is available as he failed to report back.

Case (58) J.P. Male aged 51.

History

This man was seen on 23.7.54 complaining of pain in the right loin of six months duration. There were no associated urinary symptoms.

Urological Investigation.

On clinical examination the right kidney was palpable but not tender.

Excretion urography showed the left kidney to be normal but no detail could be seen on the right side.

Ascending urography two weeks later showed gross hydronephrosis of the right kidney.

He was admitted to hospital for nephrectomy.

Aortography was performed on 30.8.54.

The arteriogram showed a normal left renal blood supply whereas on the right side only a very small artery with almost no terminal divisions was seen. This denoted considerable obliteration of the vascularity extending back to the main vessels.

The nephrogram (Fig. 93) shows the affected kidney to consist of an enlarged elongated organ of poor density.

These angiographic findings suggested that extensive irreversible loss of function had taken place.

Operation.

Right nephrectomy was performed on 2.9.54. (W.B.S.) The kidney which was enlarged was grossly dilated and the parenchyma was reduced to a thin rind.

Case (59) R.M. Male aged 58.

History

This patient was referred for examination of the urinary tract on 17.8.54. He complained of pain in the left loin of several years duration. In addition to the pain he had noticed blood in the urine on several occasions.

Urological Investigation.

Clinical examination was not easy, the patient being very stout and weighing over 18 stone.

No significant abnormality was found. The urine was not infected.

Excretion urography on 17.8.54 showed no evidence of dye in the left renal area. The right kidney appeared to be normal.

On 27.8.54 left ascending pyelography was attempted but failed to produce any outline of the upper ureter and kidney.

A further attempt failed four days later.

Aortography was performed on 3.9.54.

This showed the vascularity of the right kidney to be very good. The left renal artery was very small and the main divisions thin and distracted. No branching of these vessels was seen and no appreciable nephrogram effect was evident.

A diagnosis of advanced hydronephrosis was made on these appearances.

Operation.

Left nephrectomy was performed on 7.9.54. (W.B.S.) The kidney was grossly hydronephrotic the only reasonably normal parenchyma being a small area at the upper pole. This corresponded to the only area of vascularity seen on the angiograms. (These films are not illustrated.)

Case (60) L.L. Male aged 39.

History

This patient was first seen in 1947 complaining of

pain in the left loin.

Excretion urography showed considerable hydronephrosis of the left kidney. Nephrectomy was advised but no operation was performed owing to anaesthetic difficulties.

He next reported on 28.9.54 having had recurrent attacks of severe left-sided pain.

Urological Investigation.

Excretion urography showed a faint shadow of gross intra-renal hydronephrosis and operation was advised.

After admission to hospital aortography was performed on 12.11.54. This showed the appearance of advanced hydronephrosis with obliteration of most of the smaller branches. The main vessel was quite small. (These films are not illustrated as similar ones have already been included.)

Operation.

Left nephrectomy was performed on 16.11.54. (W.B.S.) The kidney was enlarged and dilated and the main pedicle greatly reduced in size. The parenchyma consisted only of a rind of tissue about 0.5 cm. in width.

Case (61) A.H. Female aged 52.

History.

This woman was sent for urological examination on 29.3.55. She had suffered pain in the left loin for four

weeks. The pain was accompanied by some dysuria and haematuria. Frequency of micturition was present but variable.

She had experienced these symptoms five years and eight years previously and had been investigated elsewhere with negative results.

Urological Investigation.

On clinical examination she was very stout.

No renal enlargement was made out.

Cystoscopy showed a blood-stained efflux from the left ureteric orifice.

The bladder urine contained B. Coli.

Excretion urography the same day showed poor concentration of the dye. The right kidney was thought to be fairly normal but the left kidney was not well outlined.

Left ascending pyelography the following day showed hydronephrosis affecting the pelvis and calyces.

She was admitted to hospital for nephrectomy but before this was undertaken aortography was carried out on 22.4.55.

The arteriogram (Fig. 94, shows gross vascular deficiency on the left side. The renal artery is small and ends immediately after its division. There is a filling defect, probably due to athero-sclerosis, just beyond its origin. On the right side the supply is not good as regards the cortical distribution but the main vessels are of adequate calibre.

The blood supply to the left kidney is poor and suggests that the lesion is more advanced than is shown by the pyelogram.

There was no nephrogram effect on the left side and that of the right was less than normal.

Operation.

Nephrectomy was performed on 25.4.55. (W.B.S.) The kidney which was almost half the normal size consisted of a dilated sac. The pedicle was thin and small.

Histology showed marked atrophy of functioning parenchyma within which the vessels showed endarteritis and arteriolosclerosis.

The third group consists of those patients in whom the hydronephrosis was secondary to a condition other than the usual uretero-pelvic obstruction.

There were seven such cases. In three of these, the obstruction was due to tumour - Case (40)(Figs. 74, 75) due to a squamous carcinoma of the renal pelvis; Case (41) due to a papillary carcinoma of the pelvis and Case (42)(Fig.76) due to a primary carcinoma of the ureter.

These three cases have already been described in detail in the discussion of neoplasm of the upper urinary tract. No further description is necessary but reference to the

the illustrations shows the appearances of hydronephrosis secondary to such obstruction.

In the remaining four cases the dilatation of the kidney was associated with the presence of calculi and these patients are described in detail in the following section dealing with this condition.

Reference to the appropriate illustrations (Cases 76,78,79,80)(Figs. 130,132,133) demonstrates the typical angiographic findings in advanced hydronephrosis.

The last, and in many ways the most important group, consists of those patients in whom a conservative, plastic operation was performed for hydronephrosis. There were eight such cases. In addition two further cases are included as most conveniently falling into this group.

Case (62) I.H. Female aged 54.

History

This woman was first seen as an outpatient on 11.10.54. She complained of intermittent attacks of pain in the right loin. The pain which was sharp at times and referred to both iliac fossae had been present intermittently for three years. She was also subject to attacks of urinary frequency during which the urine was cloudy and foul-smelling. She had no

other symptoms referable to the urinary tract.

She had undergone appendicectomy in 1951 but this had not in any way relieved her complaint.

Urological Investigation

Clinical examination showed her to be a rather stout but otherwise healthy-looking woman.

The kidneys were not palpable but she complained of some tenderness in the right loin on pressure.

Cystoscopy showed no bladder abnormality but the urine contained enterococci.

Excretion urography on the same day showed no opaque calculus and the left kidney was normal. Only a faint outline of dye could be made out on the right side and there was obvious hydronephrosis present.

Right ascending pyelography was performed a week later on 18.10.54.

This shows (Fig. 95) considerable dilatation of the renal pelvis and calyces. The ureter is uneven and there appears to be a stenosis at the uretero-pelvic junction.

It was considered that the condition was so advanced as to require nephrectomy and she was admitted to hospital on 4.11.54.

The pyelographic appearances suggested that an accessory vessel might be a factor in the obstruction. In order to determine this and to assess function, aortography

was performed on 4.11.54.

The arteriogram (Fig. 96) shows the left kidney to have a normal blood supply.

On the right side the main artery divides close to the aorta. The main supply which is rather less than the right side is, however, adequate. The upper two-thirds of the kidney are supplied by the upper division and the upper branch of the lower division. This area has a fairly satisfactory vascularity. The lower third of the kidney is supplied by the lower branch of the lower division. This vessel is rather thinner and appears to be somewhat displaced and the cortical vessels are less prominent.

The nephrogram (Fig. 97) clearly demonstrates that there is no appreciable enlargement of the right kidney.

The density of the lower third is poorer than the remainder of that kidney but the organ as a whole has a satisfactory actual and potential vascularity and function.

Comparison of these films with the pyelogram shows that no vessel is involved in the uretero-pelvic obstruction.

The angiographic appearances clearly indicate that plastic repair rather than nephrectomy should be undertaken.

Operation.

At operation on 9.11.54 (W.B.S.) these findings were confirmed. The renal parenchyma was of normal size and almost normal consistency. Marked extra-renal hydronephrosis

was present due to extreme stenosis at the uretero-pelvic junction. No accessory vessel was present in this region.

Radical resection of the pelvis and removal of the stenosed ureter after the fashion of Anderson-Hynes was carried out.

The result of this operation was very satisfactory.

An excretion urogram (Fig. 98) two months later on 19.1.55 shows excellent concentration of the dye with considerable reduction of the calyceal dilatation.

The urographic findings in this patient were not dissimilar to those in Case (61). There is, however, a striking difference in the angiographic appearances which alone showed the necessity for nephrectomy in Case (61) and the desirability of plastic repair in Case (62).

Case (63) M.B. Female aged 35.

History

This patient was first seen in a Medical Unit complaining of headaches, palpitation and shortness of breath. She was found to have hypertension, B.P. 170/100 mm./Hg. In the course of investigation she was found on excretion urography to have a right hydronephrosis. She was referred to the Urological Department on 15.9.54 for further investigation.

Urological Investigation.

On clinical examination the hypertension was confirmed but no other abnormality was found.

Examination of the excretion urogram, however, shows (Fig. 99) well-marked extra-renal hydronephrosis on the right side with dilatation of the calyces.

Cystoscopy was performed on 21.9.54, the bladder appearances being essentially normal.

A right ascending pyelogram was carried out which, however, failed to outline anything except one dilated lower calyx.

She was admitted to hospital for operative treatment and aortography performed on 15.10.54.

The arteriogram (Fig. 100) shows that the left kidney which lies low has a double blood supply. The total vascularity is normal.

On the right side the renal artery is solitary and of reasonably good calibre. Whilst the cortical vascularity is reduced the interlobar branches are of good size. The needle point lies close to the origin of the superior mesenteric artery which is well-filled and overlies the right renal blood supply to a greater extent than normal. The hepatic artery appears to arise from the superior mesenteric.

The nephrogram showed that the total vascularity and condensation of the right kidney was still very adequate.

This indicated that plastic resection should be performed.

Operation.

At operation on 18.10.54 (A.J.) the right kidney was found to be of fairly normal size and consistency. The pelvis was distended to three times the normal size and stenosis of the uretero-pelvic junction was present. No vessels were seen in this region.

Radical plastic resection (Anderson-Hynes) was performed.

Subsequent follow-up examination shows excellent function of the right kidney. An excretion urogram on 5.4.55 - six months after operation, shows (Fig. 101) good concentration of the dye and little appreciable calyceal dilatation.

Case (64) K.M. Male aged 54.

History

This man was seen as an outpatient on 4.2.55 complaining of pain in the right loin. This had been present intermittently for four months and at times had been severe. During several attacks of colic there had been associated attacks of frequency and strangury but no haematuria.

Excretion urography was carried out which showed good concentration of the dye on the left side with some

dilatation of the renal pelvis. There was, however, no uretero-pelvic constriction and the calyces were not dilated.

On the right side, dye concentration was very poor, but the appearances suggested dilated calyces. The renal pelvis was not demonstrated.

Cystoscopy was performed on 22.2.55, the appearances of the bladder being normal.

Ascending urography showed considerable hydronephrosis affecting both pelves and all the calyces of the right kidney.

He was admitted to hospital on 23.2.55 for operative treatment.

The presence of established hydronephrosis of the right kidney associated with moderate pelvic dilatation on the left side required careful deliberation regarding the correct form of treatment. The desirability of conserving the right kidney was obvious but full information regarding its actual and potential function was lacking on urography.

Aortography was performed on 25.2.55 to determine this.

The arteriogram (Fig. 102) shows a double blood supply to each kidney. On the left side the vascularity throughout the parenchyma is normal.

On the right side the distribution of the vessels is unusual. The upper main vessel divides at the aorta and the upper division runs down as far as the lower pole of the

kidney. This area is also supplied by the lower branch of the lower division. These two vessels are of considerable length and only the main branches from them may be seen. The finer vessels in the lower half of the kidney are absent.

The accessory renal artery arises below the main vessel and runs up crossing the latter to supply the region of the upper pole.

Whilst the smaller branches of the parenchyma are considerably reduced in number, the total blood flow to the kidney appears to be reasonably good.

The nephrogram (Fig. 103) shows that the right kidney is enlarged and elongated. The density is reduced, especially in the middle portion, but there appears to be adequate renal functioning tissue to permit conservation of the kidney.

Operation.

At operation on 28.2.55 (A.J.) the right kidney was found to be almost twice the normal size. Whilst obvious intra-renal dilatation was present and the parenchyma thinned, a satisfactory blood supply still existed.

Plastic repair (Anderson-Hynes) was carried out.

The subsequent progress of this patient has been satisfactory.

Case (65) E.K. Female aged 49.

History

This woman reported as an outpatient on 29.7.55 complaining of pain in the right loin. This had been constant and fairly severe for the previous two weeks. She had been seen twenty-two years previously (A.J.) with a similar complaint. At that time excretion urography, using Uroselectan B., showed dilatation of the right renal pelvis, but no operative treatment was carried out for this as she was also suffering from thyrotoxicosis.

Following thyroidectomy she felt very well and in the intervening twenty-two years had periodic discomfort in the loin until her recent attack of severe pain.

Urological Investigation.

On clinical examination she was a healthy looking woman. She had no tenderness or palpable enlargement of either kidney.

Excretion urography on 29.7.55 showed the left kidney to be normal but only one or two calyces were seen on the right side.

On 16.8.55 cystoscopy was performed which showed no bladder abnormality and the right ureter was catheterised without difficulty.

The pyelogram (Fig. 104) shows an unusual appearance. The ureter apparently deviates laterally at the level of the

iliac crest. Above this there is a large triangular area of dye. No renal parenchymal shadow may be made out. In view of the previous urographic findings it was assumed that this was a hydronephrosis but the relation of the pelvis to the kidney and the condition of the latter remained unknown.

Aortography was therefore performed on 19.8.55.

The arteriogram (Fig. 105) shows an apparently normal blood supply to both kidneys which, however, appear to be rather small.

The nephrogram (Fig. 106) shows the right kidney to be smaller than the left and to be tilted at an angle to the spine.

In conformity with the arterial supply, the nephrogram of this kidney is quite satisfactory.

It was considered that the condition was largely that of extra-renal hydronephrosis, not associated with an accessory vessel, for which plastic operation was suitable.

Operation.

The right kidney was exposed on 22.8.55. (A.J.) It was mobile with a healthy-looking parenchyma. There was considerable extra-renal hydronephrosis. Radical resection and plastic repair (Anderson-Hynes) was carried out.

The result of this operation was quite satisfactory and post-operative excretion urograms showing good function and rapid emptying from the reconstructed pelvis were obtained.

Case (66) A.M. Male aged 22.

History

This man was referred an an outpatient on 9.8.55 with the complaint of left-sided pain of four years duration.

He had been under medical treatment for duodenal ulcer during the past year, but the pain in the loin led to investigation of the upper urinary tract. An excretion urogram suggested that there was advanced hydronephrosis of the left kidney. He was sent for further urological investigation.

Urological Investigation.

Clinical examination revealed no significant abnormality. Examination of the excretion urogram showed a faint shadow in the left renal area suggestive of considerable renal dilatation.

Left ascending urography on 16.8.55 shows (Fig. 107) obstruction to the catheter and dye just below the transverse process of L.II. Beyond this and overlying the last three ribs there is a very faint shadow of the dye which suggests considerable extra and intra-renal hydronephrosis.

The information from these urograms was so indefinite that aortography was undertaken on 26.8.55 to obtain further details.

The arteriogram (Fig. 108) shows the vascularity of the right kidney to be very good. It is interesting to find

also in this case a double supply to this unaffected kidney.

The upper major vessel from which arise the adrenal arteries runs across the lower main renal artery to supply the lower pole.

On the left side the major blood supply is satisfactory. Beyond this the divisions and branches display the typical characteristics of hydronephrosis. They are lengthened and displaced and the finer end vessels are few.

No accessory vessel is present on this side and the lower major division which runs down the medial border of the kidney does not appear to constitute an obstructing band at the uretero-pelvic junction.

The nephrogram (Fig. 109) shows that the left kidney which is enlarged still has a density somewhat less than half the normal.

Under these circumstances plastic operation was considered feasible.

Operation.

At operation on 30.8.55 (W.B.S.) the left kidney was found to have a gross extra-renal hydronephrosis with a high ureteric insertion. The lower division of the renal artery was seen to run across the pelvis near to the renal hilum. It was not considered to be an obstructive factor.

The kidney itself was enlarged and somewhat flabby due to fairly marked calyceal dilatation. Nevertheless in

view of the satisfactory angiographic findings plastic resection (Anderson-Hynes) was carried out.

The result of this operation was very satisfactory, good function with resolution of the calyceal dilatation being shown on subsequent excretion urography.

Case (67) W.D. Male aged 20.

History.

This man was referred for urological investigation on 23.8.55 from another hospital. He had been admitted there three weeks previously following a complaint of dysuria and urinary frequency associated with suprapubic pain. He had no pain in his back or sides. An excretion urogram had shown a right hydronephrosis.

Urological Investigation.

On clinical examination the only abnormality found was tenderness in the suprapubic region.

Examination of the urograms showed moderate intra-renal hydronephrosis but the pelvis was not well defined.

Cystoscopy on 24.8.55 yielded a cloudy urine which proved to contain B. Proteus.

Right ascending pyelography (Fig. 110) shows moderate extra and intra-renal dilatation. Although the catheter lies within the pelvis there appears to be a constriction at the level of the transverse process of L.III.

Aortography was carried out on 26.8.55.

The arteriogram (Fig. 111) shows the right kidney to have a very good main blood supply. Comparison with the normal left kidney shows that the divisions and major branches are lengthened and somewhat distracted around the dilated calyces. The cortical supply is inferior. No accessory or aberrant vessel is seen in the region of the uretero-pelvic junction.

The nephrogram showed some reduction in density which, however, was still very satisfactory.

Operation.

The right kidney was exposed on 1.9.55. (A.J.)

The parenchyma appeared to be satisfactory and there was quite a marked pelvic dilatation. The lower division was seen to run across the pelvis near to the hilum but was not considered to be an obstructive factor.

Radical plastic resection (Anderson-Hynes) was performed.

Post-operative excretion urograms showed good function and satisfactory emptying from the reconstructed pelvis.

Case (68) M.O. Male aged 26.

History

This man was seen on 29.7.55 complaining of severe pain in the right loin. This appeared to be in the nature

of a renal colic and had been severe four days earlier. He had suffered a similar attack ten months previously. He had no other complaint.

Urological Investigation.

On clinical examination no significant abnormality was found.

Excretion urography showed the left kidney to be normal but no dye concentration was seen on the right side.

On 3.8.55 cystoscopy was performed which showed no bladder abnormality and the right ureter was catheterised.

The pyelogram shows (Fig. 112) well-marked dilatation of the renal pelvis and a definite constriction at the ureteropelvic junction. The minor calyces, however, retain their normal cup-shaped appearance.

This suggested that the absence of function on the excretion urogram was a result of the recent attack of renal colic.

He was admitted to hospital for operation and aortography performed on 9.9.55.

The arteriogram (Fig. 113) shows both kidneys to have a good blood supply. On the left side the main artery branches shortly after its origin from the aorta. On the right side the appearances suggest that there are two arteries close to each other but the possibility of division of one vessel at the aorta cannot be discounted. In either event the

upper of these two vessels again runs down to supply the lower pole. No accessory vessel is present at a low level.

The nephrogram was normal.

Operation.

At operation on 12.9.55 (W.B.S.) the right kidney appeared to have a normal parenchyma. A moderate extra-renal hydronephrosis due to marked stenosis of the uretero-pelvic junction was present. No vessel was involved in this area. Radical plastic resection (Anderson-Hynes) was carried out, with entirely satisfactory results.

Case (69) F.M. Male aged 44.

History.

This patient was first seen on 26.10.55. He had experienced severe left-sided pain a week previously which lasted 12 hours. This appeared to be in the nature of genuine renal colic and was associated with nausea and vomiting. He had, however, no urinary symptoms such as frequency, dysuria or haematuria.

Urological Investigation.

On clinical examination he was a well-built healthy looking man. Tenderness was present in the left loin but no renal enlargement could be made out.

Excretion urography that day showed no stone in the urinary tract and poor concentration of the dye on the left

side. There appeared to be some degree of hydronephrosis but detail was poor. The right kidney was normal.

Left ascending urography was performed two days later and shows (Fig. 114) considerable apparent extra-renal hydronephrosis, the calyces mainly preserving their normal cup-shaped appearance. There is quite a definite "cut-off" and although the ureter is not defined the catheter appears to enter above the most dependent portion of the dilated pelvis.

This appeared to be a suitable case for plastic operation and as the urograms were not adequate for complete assessment of renal function it was decided to perform arteriography to ascertain this and demonstrate the presence or absence of accessory or aberrant vessels.

He was admitted to hospital and aortography performed on 4.11.55.

The arteriogram (Fig. 115) shows the right renal vasculature to be normal. On the affected side, a large accessory vessel supplying the lower pole arises from the aorta the distance of one vertebral body lower than the main artery.

Comparison with the ascending pyelogram suggests that this is definitely a factor in obstruction.

It should be mentioned here that the superimposition of the arteriogram and pyelogram is not exactly accurate. This is due to the fact that in urography, films are taken in full expiration, whereas in angiography muscular paralysis

usually means that exposure is made midway between full inspiration and expiration.

The nephrogram (Fig. 116) shows an enlarged left kidney with projection of the poles there being a marked hilar depression. The parenchymal density, however, is good and indicates very satisfactory actual and potential function.

Operation.

The left kidney was exposed on 8.11.55. (W.B.S.) It was found to be enlarged and elongated as shown on the nephrogram. There was marked extra-renal dilatation of the pelvis with kinking and stenosis at the uretero-pelvic junction. The accessory artery shown on the arteriogram along with its vein was seen to cross just above the uretero-pelvic junction, anteriorly. Although there was some degree of prolapse of the pelvis over these constricting vessels the major cause of obstruction appeared to be below this level at the stenosed uretero-pelvic junction.

Radical plastic repair after the fashion of Anderson-Hynes was carried out, the anastomosis being effected in front of the accessory vessels.

The result of this operation was very satisfactory.

Case (70) F.B. Male aged 55.

History.

This patient was under treatment for pulmonary

tuberculosis in Robroyston Sanatorium. In the course of routine examination of the urinary tract, excretion urography on 6.5.55 showed a degree of intra-renal hydronephrosis of the right kidney. The urine was negative for M. tuberculosis.

Cystoscopy on 10.5.55 showed no abnormality but right ascending pyelography shows (Fig. 117) marked extra-renal dilatation to be present. The pelvi-ureteric obstruction lies between the second and third lumbar transverse processes.

Aortography was carried out on 24.8.55.

The arteriogram shows (Fig. 118) the left renal vascularity to be normal. On the right side the appearances are typical of moderate hydronephrosis. The main divisions and branches are attenuated and somewhat displaced with diminution of the cortical arborisation. The main lower division arises well clear of the hilum and its terminal branch runs down to supply the lower pole. In addition there is a thin vessel arising from the main artery near the aorta which runs down to the lower pole in a graceful convex curve. This aberrant vessel may well be an obstructive factor.

A faint nephrogram shadow is present even on this film and suggests that the kidney is not greatly enlarged and of reasonable function. This was confirmed by the later true nephrogram phase..

Comparison with the ascending pyelogram suggests that the lower division is not a primary obstructive factor.

In view of the absence of urinary tract symptoms and the presence of an open pulmonary tuberculous lesion, operation has not been carried out on this patient although the kidney is suitable for plastic repair.

Case (71) C.M. Female aged 50.

History

This patient was sent for urological investigation on 1.4.55 for several reasons.

Four years previously she had "kidney trouble and took fits". She was examined in hospital in America and told that she had high blood pressure and hydronephrosis. No operative treatment was carried out and she was put on a salt-free diet. Since January, 1955, she had suffered intermittent attacks of haematuria and urinary frequency but she had no complaint of pain referable to the upper urinary tract.

She had undergone three major gynaecological operations within the last fifteen years.

Urological Investigation.

On clinical examination she was a stout unhealthy pale-looking woman. The blood pressure was 165/110 mm./Hg.

Cystoscopy was performed which showed no bladder lesion to account for the haematuria.

Excretion urography was performed the same day which showed only a faint suggestion of the dye in the right kidney.

No detail could be made out.

On 27.4.55, bilateral ascending urography was carried out. This shows (Fig. 119) fullness of the left renal pelvis and clubbing of the minor calyces. On the right side the dye has been greatly diluted and only the faint outline of a large hydronephrotic kidney can be seen. These appearances suggested that the left kidney was not much affected whereas the right would require removal. On the other hand the excretion urogram had shown no dye on the left side.

Aortography was performed on 29.4.55.

The arteriogram (Fig. 120) shows that on the left side there is gross vascular deficiency. The renal artery although of normal calibre at its origin very quickly tapers and the main divisions are extremely thin with no appreciable parenchymal supply.

On the right side there are two vessels arising very close to each other. These have probably a common posterior origin. The divisions and branches from these show the characteristic displacement, thinning and lengthening of hydronephrosis. The irregularity of the aorta is due to athero-sclerosis.

The nephrogram shows (Fig. 121) that the right kidney is enlarged and has a greatly reduced density although the lower pole concentration appears adequate. There is complete

absence of nephrogram effect on the left side.

These angiographic results clearly demonstrated that removal of the right kidney could not be undertaken.

In view of this it was decided to attempt a plastic operation on the right kidney to improve its function.

Operation.

The right kidney was exposed on 5.5.55. (A.J.) It was found to be a soft flabby enlarged kidney. The ureter was felt as a hard fixed rigid structure running into a pelvis of similar consistency. As both the ureter and pelvis were bound down and matted it was deemed inadvisable to attempt to free these and perform a plastic operation which had little hope of success.

Nephrostomy drainage was therefore instituted.

The subsequent progress of this patient was satisfactory, the renal sinus closing quickly after removal of the tube. No further information regarding this patient is available as she returned to Canada some weeks after discharge from hospital.

Angiography in this case had a valuable influence on the management of the patient. It clearly showed that the impaired vascularity of the left kidney rendered that organ incapable of maintaining adequate renal function. This was not ascertained definitely on urography. The angiograms in

this case showed beyond all doubt that it was imperative to conserve the right kidney. The fact that the state of the pelvis and ureter and the presence of dense adhesions precluded the possibility of plastic repair does not detract from its value.

SUMMARY AND CONCLUSIONS.

The claims made in the introduction to this section regarding the value of angiography in hydronephrosis have been justified by the results obtained in these twenty-six cases.

Accessory vessels, where present, were shown and their relation to the renal pelvis demonstrated by comparison with the urograms.

In this connection the wide divergence of views in attributing obstruction to such vessels (Anderson, 55%, Meredith Campbell, 4%) may be due to a failure to distinguish between the two types. It is suggested that the term accessory artery be reserved for one which arises from the aorta additional to a normal renal artery. Usually such vessels

arise below the normal one and supply the lower pole.

Occasionally, as in Cases (64, 66, 68) it may arise above the main vessel which it crosses in its course to the lower pole. These polar arteries may at some stage of pelvic dilatation constitute an obstruction.

Aberrant arteries should be regarded as those divisions of a single renal artery which arise further from the renal hilum than usual and run to one pole. On occasion such lower polar arteries may cause urinary obstruction.

Unless at operation the polar artery is followed to its origin the distinction between them cannot be made.

Arteriography will, however, accomplish this with greater ease and equal certainty.

Until the present investigation it had been my impression that accessory or aberrant arteries were a frequent cause of uretero-pelvic obstruction. The arteriographic and operation findings which have been noted in detail have, however, proved otherwise.

Excluding Group Three cases, accessory vessels were present in 6 out of 19 cases. A double blood supply to both kidneys was present in 3 instances. (Cases 53,54,64). In none of these was the vessel considered to be a causal or contributory factor in obstruction, either on arteriography or at operation where performed.

In 2 cases (63,66) an accessory artery was present

on the other side, the affected kidney having a normal single renal artery.

In two patients only were lower polar vessels present on the affected side. In Case (69) the accessory artery was considered a contributory factor and may perhaps have been causal. In Case (70) the aberrant artery may also have been an important factor but no operative proof is available.

It is felt that the employment of arteriography can contribute to the assessment of the incidence and relationship of such arteries to urinary obstruction.

The modern plastic operations do not entail division of a polar artery but where such is contemplated the extent of parenchyma supplied is clearly shown.

An accessory vessel does not necessarily mean an artery and occasionally a lower polar vein may be the cause of obstruction. Arteriography will not demonstrate such a vessel.

The second and major contribution - namely an assessment of renal function based on the angiographic appearances - has been shown in every case.

In minor hydronephrosis where adequate function is indicated by good urograms, angiography is not necessary.

In the four patients (Cases 53,54,55,56) aortography was carried out to prove the close correlation between vascularity and function.

In the more advanced hydronephrosis, especially where the excretion urograms are equivocal, it has a definite value.

In the second and third groups, excretion urography failed to give accurate information regarding function in 9 out of 12 patients. In these 9, inadequate potential as well as actual function was shown beyond doubt by angiography. In the remaining 3 patients (Cases 57,60,61) in which dye concentration was present, the arteriograms clearly showed that nephrectomy was necessary and that function was reduced beyond hope of reasonable improvement.

In the last group, in which plastic repair was done, the procedure proved most helpful. In 3 of the 10 patients (Cases 63,67,70) the adequate function shown on urography was confirmed and in addition the state of the contra-lateral kidney was shown.

In the remaining 7 cases, angiography gave an assessment of function and demonstrated the feasibility of conservative surgery when urography failed to do so.

The desirability of plastic repair rather than nephrectomy based on the angiographic findings does not take into account other factors such as local infection.

The last patient (Case 71) illustrated this point but at the same time the necessity of preserving the hydronephrotic kidney was shown only by angiography.

HYDROCALICOSIS.

Dilatation of the renal calyces follows obstruction to their urinary outflow. In the majority of cases of renal obstruction the lesion lies at or below the uretero-pelvic junction and the resultant condition is that of hydronephrosis.

Less frequently, the obstruction may be local so that one or more calyces only are affected resulting in hydrocalicosis.

There are three causal factors in the production of such a defined dilatation.

The occurrence of stone confined to a calyx may result in blockage of the urinary output.

Following inflammation, a degree of fibrosis may occur resulting in dilatation, a condition described by Braasch (1928) as "localised obliterating pyelonephritis."

In the absence of any mechanical cause, the condition has been attributed by Moore (1950) to an achalasia of one or more of the calyceal sphincters.

The changes in the pathological anatomy depend not so much on the cause as the site of the obstruction. Thus the dilated area may communicate with a major calyx, with other minor calyces or with the pelvis.

The diagnosis is made on urographic examination.

This will demonstrate the dilated calyx and its slow

emptying. The relationship of stones if present will be seen.

Surgical treatment offers the only cure where symptoms are present. This may take the form of:-

1. The opening of the dilated calyx through a nephrotomy incision, followed by the dilatation of the communication into a normal calyx or the pelvis. The cavity may be obliterated by sutures or closed around a nephrostomy tube for drainage.

2. Partial nephrectomy which removes the affected area.

There is little doubt that the latter procedure affords much better results and is the operation of choice.

Angiography which is not diagnostic of the condition may, however, prove helpful in two ways.

It will afford further information regarding any degree of ischaemia of the affected part of the kidney.

More important, the demonstration of the blood supply to the area to be removed has a practical application in the operation of partial nephrectomy.

This will be discussed in greater detail in connection with renal calculi.

The opportunity has arisen of examining four patients with hydrocalicosis.

Case (72) J.M. Male aged 19.

History

This young man was referred for urological examination on 22.12.54. He had suffered fairly constant severe pain in the right loin for the previous three weeks. The pain was also experienced in the right hypochondrium and iliac fossa.

He had associated urinary frequency and discomfort on micturition.

Urological Investigation.

Apart from tenderness in the right loin no other clinical abnormality was found.

Excretion urography showed that the upper calyx of the right kidney was dilated. On the left side the upper calyx had an elongated neck but was otherwise normal.

The urine was infected with Staph. Aureus.

It was considered that his symptoms were due mainly to the urinary infection and antibiotic and sulphonamide therapy was prescribed to eradicate this.

He reported back on 28.1.55 still complaining of fairly constant pain on the right side although the associated urinary symptoms had subsided.

The urine was now free from infection.

Excretion urography was repeated which confirmed a persistent dilatation of the upper calyx of the right kidney.

On 11.2.55 cystoscopy was performed which showed no

bladder abnormality.

Right ascending pyelography shows (Fig. 122) dilatation of the upper calyx. Unlike the excretion urograms the neck of the calyx appears to be wide but, on withdrawal of the catheter and subsequent X-Ray, definite delay in emptying was demonstrated.

In view of the persistence of pain it was decided to remove the upper segment but before doing so aortography was performed on 14.2.55.

The arteriogram (Fig. 123) shows a very normal blood supply to the right kidney. The upper pole is supplied by two branches which arise from the main artery outside the kidney. There is no vascular deficiency in this area. The possibility of extra-renal ligation of these vessels before resection was demonstrated.

The nephrogram appeared to be quite normal.

Operation.

The right kidney was exposed on 17.2.55. (A.J.) The two branches to the upper pole were identified but during clearing of the upper segment, the upper of these vessels was torn. The bleeding point, however, was easily identified and ligated. Resection of the affected upper segment was carried out after formal ligation of the lower branch, no further major vessel requiring stitch ligation.

The subsequent progress of this patient has been

satisfactory and there has been no recurrence of pain.

Case (73) M.H. Female aged 49.

History

This woman was referred for urological examination on 26.5.54. She had a history suggestive of gall-bladder dyspepsia of three years duration. She complained of pain in the right hypochondrium and loin which was associated with sickness. She had no urinary symptoms.

The left kidney had been removed fourteen years before for calculus disease.

Urological Investigation.

On clinical examination no significant abnormality was made out.

Excretion urography showed a small stone in the region of the lower pole of the right kidney. The calyceal and pelvic pattern could not be made out.

On 2.6.54 right ascending urography was carried out which showed the pelvis and upper calyx groups to be normal. The lower calyx was not filled but it was considered that it contained the stone.

In view of the indeterminate findings on urography and the fact that this was a solitary kidney it was decided to employ aortography before embarking on operation.

The arteriogram (Fig. 124) shows that the needle

is inserted well below the origin of the right renal artery. The stump of the left renal artery may be seen as a small projection overlaid by the branches of the superior mesenteric vessel. The vascularity of the right kidney is good except at the lower pole where there is an absence of cortical arborisation. The terminal divisions of the lowest branch are somewhat displaced.

The nephrogram (Fig. 125) shows normal density of the upper two-thirds of the kidney. The lower third, however, is much more translucent and it was at first thought that this was a renal cyst. Study of the film, however, shows that the apparent rounded smooth edge is due largely to superimposition of bowel gas shadows.

Operation.

The right kidney was explored on 12.7.54. (A.J.) It was enlarged and there appeared to be a cystic mass at the lower pole. Two stones were removed and the lower pole resected. Examination of the latter showed that the cystic mass communicated by a tiny opening with the calyceal system. It was in fact an advanced hydrocalicosis, the obstruction being due to stone and inflammation.

Whilst it resembled a renal cyst, this appearance was due to the extreme dilatation and thinning of the cortex.

This patient's subsequent progress has been entirely satisfactory.

Case (74) M.M. Female aged 52.

History.

This woman was admitted to a Medical Unit on 15.7.55 complaining of intermittent attacks of pain in the left loin of three months duration. In addition, she had marked frequency of micturition and dysuria.

The urine which was obviously infected had not cleared in spite of several urinary antiseptics administered by her own doctor.

She also suffered from diabetes mellitus for which she received 18 units of Insulin daily.

Investigation in the Medical wards confirmed the presence of diabetes and the urinary infection due to B. Coli. neither of which, however, could be completely controlled.

She was referred to the Urological Department for further investigation on 29.7.55.

Urological Investigation.

Cystoscopic examination yielded a grossly infected urine and much debris was present in the bladder. The mucosa was lustreless and suggested a mild chronic inflammation.

Excretion urography was carried out on the same day which showed no function on the right side, the left being apparently normal.

Right ascending pyelography was performed on 1.8.55 which shows (Fig. 126) dilatation of the upper major calyx

group, the neck of which is drawn out and narrowed. It was considered that this localised dilatation might be a factor in the persistent urinary infection and that resection of the upper pole was justifiable. Before operative treatment aortography was carried out on 5.8.55.

The arteriogram (Fig. 127) shows that the main blood supply to the right kidney is good. There is some lack of cortical branching in the region of the upper pole but no other significant abnormality. No discrete branch requiring extra-renal ligation is present.

The nephrogram did not suggest any marked ischaemia round the dilated upper calyx.

Operation.

The right kidney was explored on 9.8.55. (W.B.S.)

The kidney, which was enlarged, was adherent to surrounding structures. The organ was unhealthy-looking and the appearances suggested tuberculosis. The ureter was thickened and dilated. Under these circumstances and in view of the normal left kidney it was considered advisable to remove the kidney rather than perform resection of the upper pole.

Examination of the specimen did not show obvious ulceration of the dilated calyx although it was considered that small tubercles were present in the cortex around it.

Histological examination showed numerous areas of

endothelioid and giant cells throughout the cortex which were considered to be of a tuberculous nature. Chronic inflammatory reaction was present in the wall of the ureter, pelvis and calyces but this was not considered to be histologically tuberculous in character. Acid fast bacilli were not demonstrated anywhere in the kidney.

This patient presented several puzzling features which were not clarified on urography, angiography or histology. Whilst the condition may, more correctly, be regarded as one of tuberculosis rather than non-specific hydrocalicosis, it has been described in this section because of the vascular changes occurring around the localised calyceal dilatation.

Case (75) J.A. Female aged 27.

History.

This woman was referred for examination on 30.8.55. She had suffered fairly severe constant pain in the right loin for four weeks. She had no associated urinary symptoms and haematuria had not been present.

Urological Investigation.

On clinical examination there was marked tenderness in the right renal angle but no enlargement of the kidney was felt. No other abnormality was discovered.

Excretion urography suggested some attenuation of the

right upper calyx and the possibility of a tuberculous infection could not be discounted.

Cystoscopy was performed on 6.9.55 which showed no abnormality and subsequent bacteriological reports of the urine showed no tubercle bacilli.

Right ascending pyelography was carried out at this time which shows (Fig. 128) localised hydrocalicosis affecting the upper group.

In view of the persistent right-sided pain it was decided to carry out resection of this segment.

She was admitted to hospital and aortography performed on 28.10.55.

The arteriogram (Fig. 129) shows the main right renal blood supply to be essentially normal. The parenchymal outline discernible at this stage demonstrates the right kidney to be smaller than the left. There is some deficiency of cortical arborisation in the upper pole and ligation of the upper two branches should not be performed unless resection removed half the kidney. A fairly large adrenal artery may be seen on this side - this is considered to be the inferior adrenal vessel arising from the right renal artery.

Operation.

Resection of the upper pole was performed on 7.11.55. (A.J.) During mobilisation some bleeding was encountered in the region of the upper pole. This did not arise from any

of the renal arteries but from the inferior adrenal demonstrated on the arteriogram.

The value of angiography in this case lay not only in showing the minor vascular deficiency around the dilated calyx but also the importance of avoiding formal ligation of vessels which would have led to definite ischaemia of renal tissue beyond that to be resected.

SUMMARY AND CONCLUSIONS.

These four cases show that angiography is not diagnostic of this condition which requires the localised calyceal dilatation to be outlined.

The angiographic changes consist of a degree of vascular compression and obliteration in the surrounding parenchyma.

Its main practical value lies in the determination of the blood supply before partial nephrectomy.

RENAL CALCULUS.

Urinary lithiasis is one of the commonest but most complicated conditions which arise in urology. Many complex factors, as yet incompletely understood, are involved in the production of stone in the kidney but a review of the aetiology of this disease is not pertinent here.

Calculus disease of the urinary tract presents many problems both in its investigation and management. Any diagnostic method which offers additional aid in this serious problem is worthy of trial and it is considered that renal arteriography contributes useful information in this field.

At present, in most urological centres, a patient suffering from renal calculus is submitted to a fairly full investigation.

In addition to the usual clinical examination and assessment the following special investigations are carried out.

Complete urographic examination by excretory and if necessary, ascending techniques.

Bacteriological and biochemical examinations of the urine.

Estimation of the blood electrolytes.

One or more renal function tests.

Following such a comprehensive investigation a decision is reached whether to treat the condition

conservatively or by surgery.

Every stone in the kidney is an actual or potential hazard to the patient. Surgical removal is therefore usually advisable except under special circumstances. These include a small cortical stone or one of a size which may be passed spontaneously and which has not caused appreciable dilatation of the collecting system. Also, in certain cases of large bilateral staghorn calculi, operation may not be advisable.

Apart from such special circumstances, operative treatment offers the only certain relief and is necessary for the following reasons:-

To remove the stone and associated symptoms such as pain, colic, haematuria and urinary frequency.

To eradicate or prevent infection of the urinary tract.

To prevent or arrest dilatation of the kidney.

The successful management of the case will be influenced by many factors such as the number, size, shape and position of the stones; the presence or absence of infection; the degree of anatomical and functional derangement of the kidney and the condition of the other kidney.

Until fairly recently the operations commonly employed to deal with a renal calculus consisted of nephrectomy, pyelolithotomy and nephrolithotomy with or without nephrostomy drainage and irrigation.

In spite of the increasing realisation that operation is only one part of the treatment, the recurrence rate of calculus formation remains high.

The post-operative treatment consisting of a correct diet, high fluid intake, regulation of the urinary pH and the elimination of infection is necessary and valuable but has only suceeded to a slight degree in reducing the rate of stone recurrence.

It is for this reason that urologists in recent years have tended to use more frequently the operation of resection of the kidney.

The older operations of pyelolithotomy and nephrolithotomy whilst still the operation of choice or necessity in many cases, do not constitute the correct procedure in many other cases.

These two operations merely remove the stones and fail to correct some of the underlying factors responsible in part or whole for their formation.

Partial nephrectomy removes not only the stone or stones and the debris in the adjacent renal tissue but also the affected calyx in which these stones have matured. Its value is shown by the fact that the recurrence rate after it is certainly lower than that of the other operations.

It is with particular reference to this operation that arteriography has its greatest application in calculus

disease.

There are two ways in which it may prove useful as a diagnostic aid - assessment of renal function and the visualisation of the arterial supply.

Partial nephrectomy is the operation of choice where calculi are localised to a calyx or calyces in the upper or lower poles of the kidney.

The extremities or poles of the kidney are frequently supplied by an accessory vessel or a well-defined branch from the main renal artery.

In some cases such a vessel may be formally ligated outside the kidney substance. Not only does this reduce bleeding at operation but there is the assurance that the area to be removed is restricted to that supplied by the vessel.

In other cases, the arteriogram will clearly show that the vessel supplies a larger area than that to be removed and therefore extra-renal ligation should not be done. Such information is still valuable as regards operative technique and relative haemostasis. Blunt dissection will remove renal tissue from around the larger vessels without tearing them and permit ligation to be done before they are cut. This procedure is similar to that employed in dealing with the vessels of tissues of similar consistency and structure such as the liver.

Such a manoeuvre is more easily performed where the

position and course of the branches are known and may be visualised on an X-Ray film during the operation.

The technique of formal ligation of the main vessels to the segment either outside or inside the kidney is in my opinion preferable to occlusion of the pedicle by a clamp and stitch ligation afterwards.

The control of haemorrhage by a rubber-covered clamp on the main artery is not an innocuous procedure.

Whilst deprivation of the blood supply for a short period may be quite safe, it has been proved that occlusion for one hour will be followed by severe functional impairment as shown by the Homer Smith clearance test. (Grabstald, 1951)

Such changes are present even six months after operation.

It is not unreasonable to suppose that clamping for shorter periods may in some cases have an adverse effect on function. Where operation is performed on a solitary kidney even a temporary interference in the function may be a serious matter.

Temporary manual obliteration of a branch and the observation of colour change in the kidney is inaccurate and unreliable.

In the present series aortography has been employed in several types of calculus disease.

They fall into three main groups.

Those patients in whom nephrectomy was necessary.

Those in whom the stone was removed by nephrolithotomy.

Those in whom partial nephrectomy was performed.

Where the stone has been confined to the pelvis and has caused little effect elsewhere in the kidney as judged by the usual urographic methods, aortography is unnecessary and has therefore not been employed.

The first group consists of patients in whom nephrectomy was necessary because the disease had progressed to such a degree that the organ was no longer capable of recovery of function.

There were six cases in this group.

Case (76) H.A. Male aged 67.

History

This man was sent for examination on 13.7.54. He had suffered several attacks of severe right-sided pain over the previous three years. Pain had been present continuously in the right loin for one week before examination. He had no associated urinary symptoms.

Urological Investigation.

On clinical examination there was tenderness in the

right loin and an ill-defined palpable right kidney.

An excretion urogram on the same day showed two large calculi in the right renal area where no dye concentration was obvious.

The left kidney appeared to be normal.

It seemed obvious that nephrectomy would be necessary and arrangements were made to admit him to hospital.

In order to determine the vascular appearances before operation, aortography was performed on 15.9.54.

The arteriogram (Fig. 130) shows a double blood supply on the right side. The upper vessel has a rapidly diminishing calibre and thin divisions. The lower vessel is smaller at its origin and its divisions are likewise much reduced in size. There is no finer branching and the parenchymal supply is obviously grossly deficient.

On the left side the renal artery which is overlaid in part by the splenic vessel is of good size with normal parenchymal distribution.

Only a faint nephrogram effect was present on the right side.

These appearances suggested advanced calculus hydronephrosis with global atrophy and vascular obliteration.

Operation.

Right nephrectomy was performed on 16.9.54. (W.B.S.)

The kidney was grossly hydronephrotic and the pedicle

consisted of two very small arteries as defined on the arteriogram.

On examination of the specimen, only a thin rind of parenchymal tissue remained, which on histological examination showed chronic pyelonephritis.

Case (77) E.D. Female aged 66.

History.

This patient was referred for investigation on 14.4.55. Seventeen years previously stones had been removed from the right kidney. She had felt reasonably well until a year previous to examination when she experienced pain in the right side. This was associated with urinary frequency. Four months before, the right renal wound had broken down and continued to discharge sero-purulent fluid.

Urological Investigation.

On clinical examination she was a small unhealthy-looking woman. A discharging renal sinus was present in the right loin.

Excretion urography showed a staghorn calculus in the left kidney. Two stones were present in the pelvic portion of the right ureter and no dye was seen on the right side.

Attempts at right ascending urography failed, neither the catheter nor dye ascending beyond the lower stone.

She was admitted to hospital and in view of the urographic results, aortography was performed on 29.4.55 to ascertain the state of the right kidney.

The arteriogram (Fig. 131) shows a double supply to the left kidney which contains the staghorn calculus. Whilst the cortical vascularity is poor the main blood supply appears to be moderately good.

On the right side no vascularity at all may be seen. The site of origin of the renal artery is, however, obscured by the superior mesenteric vessel but it is obvious that there can be no appreciable actual or potential renal function on that side.

The needle point is situated close to the origin of the superior mesenteric artery and the condensation of dye is more marked in that vessel than in the aorta or renal arteries.

It is interesting to note that the hepatic artery which is outlined with a comparable density arises from the superior mesenteric and not the coeliac axis.

In view of the persistent discharge from the right renal sinus it was decided to explore the right kidney and ureter.

Operation.

The right renal space was explored on 10.5.55.(W.B.S.) Much inflammatory reaction and adhesions were present but the presence of the ureteric stones was confirmed. The kidney

consisted of a tiny hydronephrotic non-functioning organ. During mobilisation and removal of the latter considerable anaesthetic difficulty was encountered. Sudden cardiac arrest occurred and in spite of all rescuscitative measures the patient died on the operating table.

Reference has been made to this patient when discussing the effects of aortic puncture and the histological findings of the aortic wall were demonstrated in Section II.

Case (78) M.M. Female aged 64.

History.

This patient was referred for urological investigation on 15.4.55. She had been under investigation in a Medical Unit complaining of lassitude, dyspnoea and urinary frequency which had troubled her for several years.

She was known to have hypertension and had been investigated elsewhere four years previously. In the course of investigation the hypertension was confirmed, the blood pressure being 255/100 mm./Hg. The urine was infected with B. Coli which although sensitive to Streptomycin had not been eradicated by the administration of that drug.

X-Ray examination had shown several stones in the right renal area. She was referred for further urological investigation.

Urological Investigation.

On clinical examination the right kidney was tender but palpable enlargement was not made out.

The urine contained B. Coli.

The hypertension remained the same. The blood urea was 48 mg./%.

Excretion urography showed one fairly large and several smaller stones in the right renal area, no dye appearing on that side.

The left urogram appeared to be normal.

Apart from the presence of hypertension it was considered that the renal symptoms and urinary infection could not be eradicated without surgical treatment for the removal of the stones.

Before deciding the form this should take, aortography was carried out on 20.5.55.

The arteriogram (Fig. 132) shows the left renal blood supply to be normal although there is some stenosis near the origin of the main vessel.

On the right side the main renal artery is narrowed and the divisions are thinned and displaced. No cortical supply may be seen.

These appearances suggested calculus hydronephrosis.

No appreciable nephrogram effect was seen on the right side - the left being normal.

It was obvious that nephrectomy was indicated.

Operation.

Right nephrectomy was performed on 24.5.55. (W.B.S.)

A grossly hydronephrotic kidney of more or less normal size was removed. The rind of parenchyma showed on histological examination chronic pyelonephritis and the changes associated with benign hypertension. Subsequent follow-up of this patient has shown that she has had a remarkable symptomatic improvement but there has been no appreciable reduction in her blood pressure.

Case (79) W.J. Male aged 41.

History.

This patient was referred on 23.8.55 from a Medical Unit. He had been under observation for five months complaining of headaches and dizzy attacks due to hypertension. The blood pressure was 170/135 mm./Hg. In the course of examination he was found to have calculi in the right kidney. He had no urinary symptoms.

Urological Investigation.

Apart from the hypertension, no clinical abnormality was found.

Excretion urography confirmed the presence of calculi in the right kidney and no dye was apparent on that side.

The left kidney appeared to be normal but a faint ring shadow was seen below the renal pelvis. This raised the possibility of aneurysm affecting the left renal artery.

In view of the presence of calculus disease associated with hypertension, nephrectomy was considered advisable.

Before doing so the vascular state of the right kidney and the presence or absence of aneurysm of the left renal artery required investigation.

He was admitted to hospital and aortography performed on 16.9.55.

The arteriogram (Fig. 133) shows the left renal vascularity to be normal. There is no evidence of the ring shadow previously noted and no aneurysm is present.

The vascularity of the right kidney is poor. The renal artery which divides close to the aorta, has a total diameter of less than half the other side. The lower part of the right kidney has practically no blood supply and the small cortical branches are lacking in the remainder of the kidney.

The nephrogram confirmed the vascular deficiency, only the upper part appearing as a shadow of greatly reduced density.

Operation.

Right nephrectomy was performed on 19.9.55. (W.B.S.)

Gross calculus hydronephrosis was present, the

pedicle being less than half the normal size. The arteriographic appearances were confirmed.

The subsequent progress of this patient has been satisfactory - the blood pressure being 140/110 three months after operation.

Case (80) J.K. Male aged 24.

History.

This patient, a seaman, was first seen on 24.4.53. He stated that he had suffered intermittent attacks of pain for the previous three years. Associated with these attacks were frequency and dysuria.

Right nephro-lithotomy had been performed in Australia one year previously but part of a stone had been left in the right kidney. He had remained fairly well until two months before examination when he had been landed at Panama and found to have a right pyelonephritis associated with stone. No operation was performed and after repatriation he was referred for further examination and treatment.

Urological Investigation.

On clinical examination he was found to have tenderness in the right loin, but no other significant abnormality was found. The urine contained B. Coli.

Excretion urography showed a large stone in the right kidney apparently occupying the pelvis. Very faint dye

excretion of some dilated calyces was seen. The left kidney appeared to be normal.

Aortography on 13.5.53 showed the right renal artery to be greatly reduced in size with no appreciable parenchymal branching.

The left kidney had a normal good blood supply.

The nephrogram effect on the right side was very faint. (These films are not illustrated.)

Operation.

Right nephrectomy was performed on 19.5.53. (W.B.S.)

The kidney which was slightly larger than normal contained a large stone. The vascular pedicle was greatly reduced in size and only required one ligature.

Intra-renal hydronephrosis was present with marked infection.

The rind of parenchymal tissue showed on histological examination the changes of chronic pyelonephritis.

Case (81) W.C. Male aged 57.

History.

This man was referred for investigation on 15.4.55. He had suffered intermittent pain in the right loin for several years. During these attacks he had associated urinary frequency and difficulty.

Urological Investigation.

No significant clinical abnormality was found. Examination of the urine was negative and yielded no growth on culture.

Excretion urography showed a dumb-bell shaped stone in the right kidney but its relation to the pelvis and calyces was not well shown.

Cystoscopy on 20.4.55 showed phosphatic debris in the bladder but no other abnormality.

Right ascending pyelography shows (Fig. 134) moderate dilatation of the kidney and most of the stone apparently lying in the lower calyx group. There is a degree of ureteropelvic stenosis beyond which the catheter has not passed.

He was admitted to hospital with a view to operation.

Aortography was carried out on 27.5.55 and the arteriogram (Fig. 135) shows a reasonably good main blood supply to the affected side. The lower branch of the upper main division is the major supply to the affected area and the appearances suggested that ligation of this vessel and the resection of the lower pole should be done.

The nephrogram showed moderately good concentration of the upper half of the kidney but considerable deficiency of the lower half.

Operation.

On 31.5.55 the right kidney was explored. (W.B.S.)

The kidney was adherent to surrounding structures and was unhealthy looking. Although the arteriographic findings were confirmed the obvious inflammation suggested that nephrectomy rather than polar resection should be carried out. This was done. No vessel was situated near the uretero-pelvic junction.

The findings here resembled those in Case (71, Hydronephrosis) in that conservative surgery as suggested by the angiograms proved impossible owing to local inflammatory lesions.

The second group consists of six patients in whom the stone only was removed.

Two of these patients (Cases 10 and 29)(Figs. 24,25, 54) have already been fully described in the section dealing with congenital anomalies. No further reference to them is necessary.

The remaining four cases are described below.

Case (82) M.M. Female aged 61.

History.

This woman was referred for examination on 4.2.55. A week previous to this she had noticed blood in the urine which had persisted in each voiding since. She had no difficulty but had some frequency of micturition. In addition

she had experienced discomfort in the small of the back and left loin for some weeks.

Urological Investigation.

On clinical examination she was a heavily built woman with a stout abdomen. There was tenderness in the left loin but neither kidney was palpable.

Cystoscopy showed no bladder tumour but cystitis cystica involving the floor of the bladder was noted.

The urine was infected with B. Coli.

On 7.2.55 an excretion urogram showed a large stone in the left kidney and a smaller shadow in the right renal area. Dye concentration was poor on the left side but suggested gross dilatation of all the calyces.

The right pyelogram showed faint, slightly dilated calyces.

On 14.2.55 cystoscopy was repeated, the inflammatory reaction being less marked.

Right ascending pyelography was carried out to obtain greater detail of the right kidney. This shows (Fig. 136) a bifid type of pelvis, both segments being rather full and suggests a kidney of moderate size.

She was admitted to hospital for further investigation.

In view of the bilateral nature of the lesion, blood chemistry estimations were done which, however, showed no abnormality of the serum calcium and phosphorus indicative of

a parathyroid lesion.

It was considered on the urographic findings that left nephrectomy should be done but before operation aortography was performed on 5.3.55.

The arteriogram (Fig. 137) shows a double blood supply to the left kidney. The main branches are of good calibre but the size of the kidney and the presence of undoubted hydronephrosis causing obliteration of much of the cortical supply is clearly shown. The large stone appears to lie in the region of the renal pelvis.

On the right side, one renal artery of small size is shown and there is no appreciable intra-renal vascularity.

The nephrogram showed the left kidney to have reasonably good density whereas there was almost complete lack of any nephrogram shadow on the right.

These appearances led to a change in policy. It was obvious that the left kidney could not be sacrificed as the right kidney alone was incapable of maintaining adequate excretory function.

Operation.

The left kidney was exposed on 7.3.55. (A.J.) It was enlarged and although dilatation was present parenchymal tissue appeared fairly adequate.

The stone was removed through a nephrotomy incision behind the convex border and temporary nephrostomy drainage

instituted.

Chemical analysis of the stone showed it to be composed largely of cystine with some calcium oxalate and phosphate.

No surgery on the right kidney has been performed. In view of the presumed metabolic aetiology of the stone subsequent treatment has consisted of advice regarding diet and attempts to regulate the urinary pH.

Case (83) J.F. Male aged 30.

History.

This patient was first examined on 13.6.54 following an attack of right renal colic. X-Ray showed a small stone in the right kidney and one in the lower end of the right ureter. The blood pressure was 170/110 mm./Hg.

Some weeks later the latter stone was passed spontaneously.

In view of the persistence of right-sided pain he was referred to the Urological Department on 4.1.55.

Urological Investigation.

Excretion urography showed a small stone in the lower calyx of the middle group of the right kidney. The pyelographic appearances were otherwise normal.

He continued to complain of pain and it was decided to remove the stone.

Aortography was performed on 11.2.55 as the question of resection arose.

The arteriogram (Fig. 138) is not of very good quality as this patient was the subject of an experiment with crossed needles and there was some delay in taking the first film as the contact switch was not used. There is a double supply to the left kidney but the stone is shown to lie almost in the centre of the right kidney and none of the extra-renal branches are amenable to formal ligation.

Operation

At operation on 14.2.55 (A.J.) the urographic and angiographic findings were confirmed. As hemi-nephrectomy would have been necessary it was decided to adopt the simpler method of nephrolithotomy.

Case (84) C.F. Male aged 63.

History.

This man was examined on 2.8.55. He complained of severe and fairly constant pain in the left side of four months duration. This was associated with increased frequency of micturition.

Urological Investigation.

On clinical examination, tenderness was found in the left loin but there was no other significant abnormality. The urine was infected with B. Coli.

Excretion urography on 5.8.55 showed calculi in the left kidney apparently affecting the pelvis and upper major calyx group which were but faintly outlined with dye.

Cystoscopy on 10.8.55 showed no bladder abnormality of note and a left retrograde pyelogram confirmed the presence of stones and their position.

Aortography was carried out on 2.9.55 to determine the type of operation necessary with regard to the function of the kidney.

The arteriogram (Fig. 139) shows that the main blood supply to the affected side is still reasonably good, although the cortical supply is poor.

The nephrogram confirmed that this kidney had a good parenchymal density.

Operation.

The left kidney was explored on 13.9.55. (W.B.S.) The kidney was slightly enlarged but the parenchyma appeared to be good except anteriorly where it overlay the stones. The latter were removed through a radial incision and the kidney preserved.

Case (85) A.M. Male aged 43.

History.

This patient was seen in a Surgical Unit on 14.8.55 He complained of pain in the left side which had been present

intermittently for one year. In the course of investigation X-Ray showed a calculus-like shadow in the region of the left kidney. He was referred to the Urological Department for further examination on 16.9.55.

Urological Investigation.

Excretion urography shows (Fig. 140) that the left kidney is incompletely rotated and the stone apparently lies in the lowest calyx. Owing to the malrotation it is not easy to distinguish between the pelvis and all the calyces. On the right side there is moderate extra-renal dilatation of the pelvis with the appearance of constriction at the ureteropelvic junction.

Aortography was done on 30.9.55 and proved very interesting.

The arteriogram (Fig. 141) shows a moderately good supply to the left kidney and the stone lying below the needle appears to be in the lower pole of the kidney.

On the right side an aberrant vessel is clearly shown arising from the upper main division and running to the lower pole. There is an additional aberrant vessel to the upper pole. The lower polar vessel may well be a factor in the early dilatation of the renal pelvis.

The nephrogram (Fig. 142) outlines the left renal mass and suggests that the stone does not lie in the lower calyx group but nearer the pelvis.

These appearances suggested that either pyelolithotomy or partial nephrectomy should be done.

Operation.

The left kidney was exposed on 2.10.55. (A.J.) On partially mobilising the kidney the stone was felt in the pelvis and was therefore removed by pyelolithotomy. As the lower pole parenchyma appeared to be fairly normal, resection was not performed.

The last group consists of those patients on whom partial nephrectomy was performed. There were ten patients in this section but one, (Case 73, Figs. 124,125) has already been described under Hydrocalicosis and accordingly no further details are given here.

The remainder are described below.

Case (86) M.R. Female aged 34.

History.

This woman was sent to the Urological Department on 28.3.55. She complained of severe pain in both loins of three days duration. This had been acute and associated with nausea and vomiting and some urinary frequency and discomfort. She had no other complaint and had not suffered any similar pain in the past.

Urological Investigation.

On clinical examination she was a healthy-looking woman apart from some pallor. The abdomen was tender as were both loins but no palpable mass could be felt.

Excretion urography was carried out which showed massive staghorn calculus formation in the left kidney. Several staghorn type of calculi were present in the lower part of the right kidney. Dye concentration was obvious in the upper part of the left kidney and in the upper two-thirds of the right one.

She was admitted to hospital on 28.3.55 for full investigation.

The urine showed a moderate growth of B. Coli on culture. The blood urea was 20 mgm./100 ml. Biochemical estimation of the plasma phosphorus and phosphatase and serum calcium did not suggest any lesion of the parathyroid glands.

The excretion urogram suggested that the stones should be removed from the right kidney and that left nephrectomy should be performed.

Such a procedure carried with it the risk of recurrence of stone in a solitary kidney. The desirability of preserving the maximum amount of functioning renal tissue was obvious and it was decided to carry out angiography in the hope that this would afford more specific information.

This was done on 1.4.55. The arteriogram shows

(Fig. 143) a good blood supply to the right kidney. A normal renal vascular pattern is present in the upper two-thirds and the lower third containing the stones is clearly shown to be supplied by the lower and terminal branches of the lower division. The feasibility of formal extra-renal ligation of these vessels is obvious.

On the left side in spite of the massive calculosis affecting most of the kidney there is still an extremely good blood supply. Not only are the main divisions normal but there is little reduction in the interlobar and arcuate vessels.

This surprising result at once raised the issue of preservation of this kidney. It was realised that there were technical difficulties in the removal of all calculus fragments and a possibility of recurrence of stone. Nevertheless, it seemed justifiable to do this in the presence of such good vascularity rather than to perform immediate nephrectomy.

The nephrogram confirmed the arteriographic findings. Whilst the lower third of the right kidney was somewhat deficient, a normal density was present in the remainder of that kidney.

On the left side, the nephrogram density suggested good cortical functional activity.

Accordingly it was decided to carry out resection of the lower pole of the right kidney followed by resection of the lower pole of the left kidney along with removal of the

remaining stones.

Operation.

The right kidney was explored on 4.4.55. (W.B.S.)

The two large arteries running to the lower pole were identified outside the kidney and formally ligated. Thereafter resection of the whole segment containing the stones and dilated calyces was effected with ease and absence of serious bleeding.

Three weeks later on 24.4.55, the left kidney was explored. (W.B.S.) The lower division shown on the arteriogram was ligated outside the kidney. Resection of the lower pole and the contained calculi was then performed, stitch ligation being necessary for the other main branch supplying this area.

Before suture of the kidney a large calculus occupying the pelvis was removed via the dilated neck of the lower major calyx group. The calculus fragments in the upper half of the kidney were removed through a nephrotomy incision and nephrostomy drainage instituted.

The subsequent progress of this patient has been very satisfactory although some tiny calculus fragments persist in the upper part of the left kidney.

Case (87) T.K. Male aged 58.

History.

This man was sent for examination on 10.12.54. He complained of intermittent attacks of pain in the right loin radiating to the right iliac fossa. These bouts of pain were associated with urinary frequency and severe nausea.

Urological Investigation.

On clinical examination he was a rather pale slightly built man. There was marked tenderness in the right renal angle and enlargement of the liver.

X-Ray of the abdomen showed two large calculi in the region of the right kidney.

Excretion urography on 14.12.54 confirmed this and showed that they lay in the lower part of the kidney. The outline of the middle and upper calyces was normal as was the left kidney.

At the patient's request, admission to hospital for operative treatment was delayed for two months.

As this seemed a suitable case for partial nephrectomy, aortography was carried out on 17.2.55 to determine the vascular supply to the lower pole.

The arteriogram (Fig. 144) shows that the lower division of the main artery which supplies the affected area arises well clear of the renal parenchyma. No appreciable supply derives from the upper division.

The lower branch of the main artery is very amenable to ligation outwith the kidney as its supply is restricted to the area of tissue requiring resection.

The nephrogram showed that the upper and middle segments of the right kidney were of normal vascular density whereas the lower third mainly occupied by the large stone was somewhat more translucent.

Operation.

Resection of the lower pole was carried out on 11.2.55. (W.B.S.) The arteriographic appearances were confirmed and formal ligation of the lower division was performed. One small vessel only required stitch ligation, bleeding otherwise being minimal. Fig.(145) shows the resected tissue and contained stones.

The subsequent progress of this patient has been entirely satisfactory, post-operative urograms showing good function of the remaining part of the right kidney.

Case (88) T.J. Male aged 39.

History.

This man was sent for examination on 12.11.54. He had suffered an attack of left renal colic two weeks previously and this had been followed by constant abdominal pain and haematuria.

Urological Investigation.

Apart from tenderness and muscle rigidity in the left loin and hypochondrium no other abnormality was found.

Excretion urography showed a stone in the lower pole of the left kidney. The function of the latter was good and the stone was situated in the lowest calyx.

Cystoscopy on 23.11.54 showed no bladder abnormality and left ascending pyelography confirmed that the stone was still present in the lowest calyx which was dilated. (Fig.147)

In view of the persistence of pain and haematuria it was decided to remove the stone.

As this seemed a suitable case for resection, aortography was done on 21.1.55.

The arteriogram (Fig. 148) shows that there is a double supply to the left kidney. There is an accessory vessel arising from the aorta above the main renal artery which it crosses to run down and supply the lower pole. The clarity of this film is not perfect as a certain amount of respiratory movement has caused some blurring.

The nephrogram (Fig. 149) was normal, the relation of the stone to renal tissue being clearly shown.

Operation.

Resection of the lower pole of the left kidney was performed on 25.1.55. (W.B.S.) The accessory artery shown on the arteriogram was displayed and its course to the aorta

above the main vessel confirmed. It was ligated before entering the lower pole which was then removed by the usual wedge resection. One small vessel required stitch ligation.

Fig. (146) shows the resected area and contained stone. Although the latter is of small size the calyx in which it matured was markedly dilated and a generous resection was necessary to remove this.

The subsequent progress of this patient was quite satisfactory, and post-operative excretion urograms have shown excellent function of the remaining two-thirds of the kidney.

Case (89) J.M. Male aged 41.

History

This man was admitted to a Surgical Unit on 30.3.55 with a history of intermittent abdominal pain associated with rectal bleeding. No abnormality of the gastro-intestinal tract was found but X-Ray showed opacities consistent with bilateral renal calculi. He was referred on 20.4.55 to the Urological Department.

Urological Investigation.

On direct questioning he admitted to attacks of pain in both loins but no clinical abnormality of the urinary tract was found.

Excretion urography showed one large and two small stones in the right renal area but no dye concentration was

seen on that side. Two small calculus shadows were seen in the left kidney the larger being in the pelvis and the smaller in the lower pole. Dye concentration was satisfactory on this side.

The urine was infected with Staph. aureus and B. Coli.

Operative treatment was advised and he was admitted to hospital on 8.7.55.

Further X-Ray confirmed that there was no alteration in the size or position of the stones.

Aortography was performed on 10.7.55 as the functional state of the right kidney was unknown.

The arteriogram shows (Fig. 150) that there is still adequate vascularity on this side. The large stone appears to be situated in the renal pelvis and the two smaller stones in the lower pole. The blood supply to this area derives from the lowest branches of the upper and lower major divisions and these arise outside parenchymal tissue.

On the left side, the blood supply to the lower pole which contains the small stone consists mainly of the lowest branch of the lower division.

The nephrogram showed good concentration of the left kidney but definite deficiency of both poles, especially the lower on the right side. It was decided to carry out resection of the right lower pole and removal of the pelvic stone followed by a similar procedure on the left side.

Operation.

The right kidney was explored on 15.7.55. (W.B.S.) The kidney was somewhat enlarged due to dilatation affecting both poles where the parenchyma was thinned. The middle segment appeared to be normal.

The large stone appeared to fill the renal pelvis and it was removed through a pyelotomy incision. Thereafter the two branches to the lower pole shown on the arteriogram were dissected clear and ligated outwith the kidney. The resultant colour change was considered to be below the line of section required for the dilated lower calyx group. A generous wedge excision was carried out which entailed encroaching on the blood supply of the middle segment. Bleeding occurred from the three terminal branches shown in this area but was easily controlled by stitch ligation.

The renal tissue, however, appeared to be somewhat unhealthy and inflammatory changes were present in the renal pelvis. Some doubt was raised at operation whether uncomplicated healing would occur.

The subsequent progress was satisfactory until the tenth day when the patient had marked haematuria. This persisted for eight days after which it cleared and there has been no recurrence.

The left kidney was explored on 4.11.55. The stone was easily removed by pyelolithotomy but polar resection was

not performed as the kidney appeared to be unhealthy and infected.

Case (90). D.T. Male aged 57.

History.

This man was sent for investigation on 10.12.54. He had suffered two attacks of pain in the left loin associated with frequency of micturition and dysuria. He had been treated by his own doctor with Sulphonamide with temporary improvement but the pain in his left side persisted.

Urological Investigation.

No significant clinical abnormality was found. The urine was infected with B. Coli.

Excretion urography showed a calculus-like shadow in the upper part of the left kidney but no obvious excretion was noted on this side whereas concentration of the dye was good on the right side.

A week later left ascending pyelography was attempted but failed. This was repeated on 21.12.54 with success and showed a stone lying near the upper calyx.

He was admitted to hospital later and on 4.2.55 aortography was carried out.

The arteriogram shows (Fig. 151) some deficiency of intra-renal vascularity although the main supply is good. The upper pole with the contained stone is especially lacking in

smaller arterial branches. No branch to this region appears to be accessible for ligation outside the kidney.

The nephrogram showed reduction in density but still appeared adequate from the functional aspect.

Operation.

The left kidney was explored on 7.2.55. (A.J.) The stone was easily palpable in the upper pole and it was at first decided to perform nephrolithotomy. After incision of the kidney it was found that the calculus was embedded in parenchymal tissue and it was judged wiser to remove the whole affected area. This was done and brisk bleeding necessitated the temporary application of an occlusion clamp. The absence of arteries outwith renal tissue was confirmed.

Subsequent progress of this patient has been quite satisfactory.

Case (91) J.J. Male aged 56.

History.

This patient was sent for urological examination on 25.3.55. He had suffered an attack of left renal colic associated with haematuria some days previously.

Urological Investigation.

Apart from tenderness of the left kidney no other clinical abnormality was noted.

The urine was infected with B. Coli.

Excretion urography showed a stone in the lower calyx of the left kidney. The renal function on each side appeared to be satisfactory.

He was admitted to hospital and aortography carried out on 25.5.55.

The arteriogram shows (Fig. 152) that there is one vessel - the lower branch of the upper division - which runs to supply the area which includes the stone. This is suitable for ligation after its point of division. Above this is a further vessel - the lower branch of the main division - but its upper terminal supply runs to an area beyond that to be resected and therefore should not be ligated.

The nephrogram showed both kidneys to have good functional capacity.

Operation.

The left kidney was exposed on 27.5.55. (W.B.S.) The first vessel described on the arteriogram was formally ligated after which resection was carried out through the neck of the lower calyx. Bleeding from the other vessel, whose position was anticipated, was controlled quickly by stitch ligation and occlusion of the main pedicle was not necessary.

This patient's subsequent progress has been quite satisfactory.

Case (92) T.C. Male aged 35.

History.

This patient was sent for urological examination on 29.8.55. He had suffered a severe attack of left renal colic a week previous to this. He had been X-Rayed four years before with negative result for a similar complaint.

Urological Investigation.

No clinical abnormality was found.

Excretion urography on 29.7.55 showed a small calculus in the lower pole of the right kidney. It appeared to occupy a cavity communicating with the lower calyceal system. The function of the kidney was satisfactory. This seemed a suitable case for partial nephrectomy.

He was admitted to hospital and aortography was performed on 29.8.55.

The arteriogram shows (Fig. 153) a good normal blood supply to each kidney. On the right side the area containing the stone is supplied by branches which arise from both upper and lower major divisions. Altogether four good-sized arterial branches may be seen to supply the affected area.

This film, which also shows an early parenchymal outline, demonstrates that ligation of these vessels can only be performed within parenchymal tissue either after blunt dissection or by underrunning with a stitch after severance. The importance of this film is that ligation of the lower

division entering the lower part of the hilum can not be performed as it is clearly shown to supply not only part of the lower but also the middle and upper segments.

The nephrogram showed no appreciable ischaemia of the lower pole in conformity with the good blood supply.

Operation.

The left kidney was exposed on 2.9.55. (W.B.S.) The absence of any artery outside the kidney below the level of the renal hilum was confirmed.

After reflexion of the capsule, a wedge of tissue containing the stone was removed. This was effected by using sharp and blunt dissection. The latter enabled two of the vessels to be ligated formally before severance whilst anticipation of the position of the other two arteries allowed rapid stitch ligation with a minimum of blood loss.

Case (93) J.H. Male aged 20.

History.

This young man was sent for urological examination on 11.3.55. He had suffered pain in the right loin for some three months and this had been associated on several occasions with haematuria. He had no other urinary symptoms and the urine was not infected.

Urological Investigation.

No significant clinical abnormality was found.

Excretion urography showed a small stone in the right kidney occupying the lowest calyx which was dilated. Renal function of both kidneys was quite satisfactory.

He was admitted to hospital with a view to resection of the lower pole.

Aortography was carried out on 14.4.55.

The arteriogram (Fig. 154) shows a good blood supply to each kidney. The area of kidney containing the stone is supplied by an artery which crosses the main pedicle and runs down outside the renal hilum to enter the lower pole direct. This artery is obviously suitable for extra-renal ligation and the area of section between the blood supply from it and that deriving from the main pedicle is clearly shown.

The nephrogram showed excellent vascularity and function of each kidney.

A few days after admission to hospital the renal symptoms subsided and in view of this and a recent bronchial infection, operation was postponed.

Following further attacks of severe pain and haematuria he was readmitted to hospital on 22.9.55.

Operation.

The right kidney was exposed on 23.9.55. (W.B.S.)

The vessel shown on the arteriogram was easily displayed and ligated. Resection was carried out through the area suggested on arteriography. Bleeding was not a

feature and no further vessel required to be stitched.

The small stone which had become displaced into the pelvis was easily extracted through the cut neck of the lower calyx which was sutured.

Subsequent progress of this patient has been quite satisfactory.

Case (94) E.B. Female aged 47.

History.

This woman attended a Surgical Unit in July, 1955 for investigation of epigastric pain and dyspepsia. These symptoms had been present for six years. Investigation of the gastro-intestinal tract and gall bladder showed no abnormality but X-Ray revealed a large calculus-like shadow in the right renal area. She was referred for urological examination on 2.8.55.

Urological Investigation.

Clinical examination revealed no significant abnormality although she complained of pain and tenderness in both loins and in the epigastrium.

An excretion urogram confirmed a stone in the lower pole of the right kidney which appeared to be rather small. The left kidney was normal. As this was thought to be a suitable case for resection, aortography was done on 30.9.55.

The arteriogram shows (Fig. 155) the right kidney

to be small and high-lying with a reasonably good main blood supply.

No obvious vessel supplies the lower pole from outwith parenchymal substance.

The vascularity of the left kidney was normal.

The nephrogram confirmed reasonably good function of the upper two-thirds of the right kidney.

Operation.

The right kidney was exposed on 4.10.55. (W.B.S.) It was small but the long vascular pedicle allowed excellent mobilisation. The stone was easily palpable in the lower pole, the renal tissue overlying it being thin and unhealthy looking.

As no extra-renal vessels were accessible for ligation the capsule, which was adherent, was stripped back and a wedge of tissue containing the stone and dilated lower calyx removed by sharp and blunt dissection. The latter permitted two vessels near the medial border at the lower angle of the hilum to be grasped and ligated.

This patient's progress has been quite satisfactory.

SUMMARY AND CONCLUSIONS.

The findings in these patients confirm that angiography can provide useful information in the management of renal lithiasis.

The determination of the degree of renal function is of considerable practical importance in deciding whether nephrectomy or preservation of the kidney should be performed. In this respect it is analogous to hydronephrosis and indeed, in a number of cases dilatation of the kidney is associated with the presence of stone.

The employment of renal angiography merely to determine function is not necessary in a large number of cases of calculus disease. Thus, in the Group III type where partial nephrectomy is the operation of choice, adequate function will usually be shown on urography. The use in such cases is to demonstrate the course of the vessels to the affected area.

Similarly, it is not necessary in Groups I or II where the urographic outline is satisfactory. In cases where no dye concentration is seen or doubt remains regarding the state of either kidney, angiography is particularly valuable.

Thus, in Group I of this series no dye was seen in the first four patients (Cases 76,77,78,79). In case (77) however, calculus blockage of the ureter was present and it

was possible that adequate renal reserve, not shown on urography, might still exist. Angiography confirmed not merely the loss of actual but also of potential function.

In Case (80) some function was shown on urography but the angiographic appearances clearly showed that this was insufficient to justify preservation of the kidney. Case (81) had a similar poor density on urography but angiography suggested more clearly that preservation of part of the kidney was possible on functional grounds. This did not prove advisable at operation owing to local inflammatory changes. This limitation of the value of the procedure is acknowledged in these circumstances. Such criticism, however, is not restricted to angiography and any form of renal appraisement is subject to the operative findings.

In Group II, Case (82) proved the value of the functional estimation of the kidneys by angiography. Urography suggested that the left kidney should be removed as function existed on the right side and ascending pyelography appeared to show a kidney not greatly affected. The arteriogram and nephrogram demonstrated that, in fact, the functional capacity of the latter was poor and that the left kidney should be preserved. This important change of policy was due entirely to aortography.

In the remaining cases in this group the procedure was not perhaps necessary but it did furnish additional

information regarding function and also the position of the stone relative to the clearly defined parenchymal mass.

Apart from the knowledge of the function of the kidney which is important in Groups I and II the greatest application of angiography in lithiasis lies in the pre-operative demonstration of the course and supply of the arterial branches in the Group III (Partial Nephrectomy) type.

Case (86) was a striking example of this in that bilateral partial nephrectomy - accurate, easy and relatively bloodless - was possible and preservation of renal tissue achieved rather than removal of the whole of the left kidney as suggested by urography.

In the remaining nine cases formal ligation of an extra-renal vessel, whose exact distribution was known, was feasible in five patients. In the remaining four, however, no extra-renal vessel was ligated. In Cases (92 and 94) blunt dissection within parenchymal tissue followed by formal ligation was easy as the position and course of the vessels were known. In Cases (73 and 90) formal ligation within the kidney was not performed and it was clearly shown in Case (90) that extra-renal ligation of the lower branch of the main division could not be performed with safety.

These cases demonstrate the contribution which angiography can make to the management of renal lithiasis.

RENAL TUBERCULOSIS.

The diagnosis of tuberculosis of the kidney is usually made as a result of special investigations. The most important of these is the bacteriological examination of the urine. The extent to which the tuberculous process has advanced in the kidney is most readily assessed by urography.

In the earliest stage of the disease - tuberculous bacilluria - no radiological abnormality will be seen as the lesion is confined to the cortex.

Once the calyces are involved the characteristic picture is produced. As function of the kidney persists for a long time, these changes may usually be shown on excretion urography. This examination will permit an assessment of the progression or recession of the condition. It is of the greatest importance not only in the diagnosis but also in the management of this disease that there should be clear and complete pyelographic pictures. It is for this reason that ascending urography is absolutely essential where there is the slightest doubt concerning the lesion or the integrity of the kidney. It is not uncommon, however, to find that the pathological changes in the kidney are more advanced than the radiological appearances. Where the lesion is very extensive, especially with closed pyonephosis, no urographic outline is possible either from failure of renal function or obstruction

to instrumental examination.

Modern chemotherapy has contributed much to the treatment of tuberculosis and in conjunction with advances in urological surgery has produced a change in the management of some of these cases.

The operation of partial nephrectomy is now performed in certain circumstances. Several objections, however, have been raised against its employment in tuberculosis.

From the technical aspect it was feared that the procedure would be complicated by secondary haemorrhage or urinary fistula. Further, that should later nephrectomy be required, this operation would be more difficult. Such complications are largely a matter of surgical technique and have, to a great extent, been overcome.

Another objection put forward was the risk of haematogenous dissemination of the disease. The danger of acute miliary spread has almost been eradicated by the use of chemotherapy, particularly streptomycin.

The third and most serious objection is based on pathological grounds, namely the inadequacy of the operation in removing only part of the disease as a tuberculous kidney may have multiple cortical foci in addition to an obvious main calyceal lesion.

This apparently serious objection takes no account of the management of the condition as a whole. Nephrectomy

is not employed only in the hope of totally eradicating the disease. It is employed for an advanced lesion even where it is known that the other kidney has a minor degree of tuberculosis. The object is such circumstances is not the eradication of the disease but the removal of a major lesion in the hope of preventing or arresting more serious complications such as cystitis and also permitting an improvement in the patient's resistance.

The rationale of partial nephrectomy is similar. It is employed to remove the part of a kidney which is diseased and functionless, the remainder being apparently normal and of good function. This applies also to removal of the clinically diseased part of one kidney whose fellow has already been removed for tuberculosis or some other condition. The preservation of renal tissue seems desirable in a disease so apt to be bilateral and liable to cause impairment of function from the back pressure effect of ureteric stenosis.

Aortography has not been used to any extent in tuberculosis in this country or in America. The only major series with a detailed report of its application in renal tuberculosis so far published is that of Weyde (1951) of Oslo. His experience of 61 cases suggests that further useful information, not obtained by urography, may be furnished by angiography.

Weyde found that, in a number of cases, the extent of the lesion could be visualised and assessed on the arteriogram and nephrogram. The vessels near the destroyed parts of the parenchyma were atrophic and irregular and often had an abrupt termination. This avascularity of the ischaemic focus was even more clearly demonstrated in the nephrogram and a truer appreciation given of the extent of the lesion than is possible on urography. He considered that the estimation of the blood supply and the function of the kidney afforded great help in determining the safe extent of the resection when partial nephrectomy was applicable.

In the present series fifteen patients in Robroyston Sanatorium with tuberculosis of the urinary tract have been submitted to aortography. No attempt has been made to subdivide them according to the type of lesion and whether unilateral or bilateral. In a number of cases a considerable interval of time elapsed between the urographic and angiographic examinations during which various forms of chemotherapy were administered.

Those patients showing some vascular abnormality associated with the lesion are described first.

Case (95) W.P. Male aged 48.

History.

In April, 1954 this patient noticed a swelling in the perinaeum associated with frequency and dysuria. This was treated in the local hospital and he was discharged home at the end of the month. He was re-admitted to hospital on 11.7.54 with a discharging sinus and a right scrotal swelling. On 3.8.54 right orchidectomy was performed, the condition being tuberculous. Following operation, Streptomycin and para-amino-salicylic acid (P.A.S.) were given and he was admitted to Robroyston Sanatorium on 23.8.54.

Examination showed an active sinus in the right scrotum and perinaeum. The prostate and vesicles were tuberculous.

The only urinary symptom was that of diurnal frequency.

Urological Investigation.

Cystoscopy on 31.8.54 showed no abnormality, the bladder capacity being large. The urine from the left kidney was T.B. positive. Ascending urography shows (Fig. 156) a normal right kidney but small irregular filling defects associated with the upper calyces of the left kidney.

Excretion urography on 3.9.54 confirmed these findings, there being an irregular elongated upper major calyx on the left side.

Aortography was performed on 9.12.54, the patient having received Streptomycin and P.A.S. for the intervening three months.

The arteriogram (Fig. 157) shows a double blood supply to the left kidney. In the region of the lesion the vascularity is good but somewhat irregular. The vessels, however, are not atrophic and ischaemia is not suggested.

The nephrogram, however, shows (Fig. 158) definite concentration of the dye around the focus of infection. This appearance is not due to calcification nor is it considered to be calyceal concentration at that early stage.

Case (96) E.L. Male aged 22.

History

This patient was admitted to Robroyston Sanatorium on 20.6.55. He complained of a swelling in the left scrotum which had been present for several weeks. Examination of the urine had shown that it contained M. tuberculosis.

Urological Investigation.

On clinical examination the left testis and epididymis were enlarged and firm. The prostate was enlarged and nodular. No other clinical abnormality was found.

Cystoscopy on 21.6.55 was normal but ascending pyelography shows (Fig. 159) a small ulcero-cavernous lesion affecting the right lower minor calyx group.

There is also some doubt regarding the integrity of the upper minor calyx. The appearances of the left kidney are normal.

Chemotherapy, in the form of P.A.S. and Isoniazid, was started on that date.

On 6.10.55 retrograde urography was repeated and showed no change in the lesion affecting the right lower calyces, the urine, however, was now negative for tuberculosis.

Aortography was carried out on 12.10.55. This shows (Fig. 160) the left renal vasculature to be normal. On the right side there is a condensation of dye comparable to the size and position of the lesion shown on urography. Beyond this the cortex shows little evidence of the fine branching.

The nephrogram confirmed the persistence of this dye concentration.

These two cases gave similar angiographic appearances in the form of increased condensation of dye in the area corresponding to the lesion. The significance of this is not easy to explain. Weyde reported similar findings in four patients who were later submitted to partial nephrectomy. In each case the lesion was surrounded by exuberant granulation tissue and he considered that the abundant capillaries were responsible for the condensation of the dye instead of the more usual avascularity in a fibrosed area. No confirmation of this is possible in the two

patients described here as operation has not been performed. If this explanation, which appears reasonable, is accepted several points of interest regarding the effects of chemotherapy are raised. In both cases the urine had been rendered negative but there had been little change in the appearance of the lesions proved by urography.

Whilst such increased vascularity might be expected following the administration of P.A.S. and Isoniazid as in Case (96) it was unexpected in Case (95). This patient received Streptomycin and P.A.S. the usual effect of which is to produce a fibrotic obliteration.

Case (97) J.K. Male aged 21.

History.

Whilst in the Army in 1953, this man suffered frequency of micturition. He did not report this until about a year later when he was referred to the Royal Infirmary on 12.5.54 for investigation.

Urological Investigation.

Excretion urography on 12.5.54 showed only inadequate concentration of the dye, the right renal pelvis being of the full type. Detail of the left kidney was lacking but the ureter was seen to be somewhat dilated.

The urine was positive for tuberculosis.

Excretion urography was repeated at Robroyston

Sanatorium on 25.5.54 and showed a filling defect at the upper pole of the left kidney. The right side did not appear to be the site of any lesion.

Treatment with Isoniazid and P.A.S. started on 31.5.54.

Ascending urography on 7.9.54 showed the right kidney to be normal, the calyces being overfilled. On the left side there were lesions associated with the upper and lower calyces. The middle group appeared to be cut-off. (Fig. 161.)

Aortography was performed on 9.12.54. (Fig. 162) There is a double blood supply to the right kidney, the main vessel supplying almost three-quarters of the organ. The total vascularity is good.

On the affected side the main renal artery is normal as far as the major divisions. This good supply is continued into the poles but the middle third segment is very avascular.

The nephrogram (Fig. 163) confirms this wedge-shaped area of ischaemia and a line of demarcation may be seen at a level corresponding to the inferior edge of the renal sinus.

These appearances suggested that the greatest area affected was the middle segment.

Operation.

The left kidney was removed on 17.12.54. (A.J.)

The pathological report states "The major lesion of

the kidney consists of a large cavity 3 x 2 cm. situated in the centre of the kidney. A further small cavity is present towards one pole".

In this case the angiographic findings appeared to be more accurate in assessing the extent of the inflammatory process than the urograms.

Case (98) W.T. Male aged 32.

History.

This man was admitted to the Royal Infirmary for treatment of a urethral stricture associated with an abscess. Investigation showed the condition to be one of tuberculosis.

Urological Investigation.

Excretion urography on 22.9.54 showed no function of the right kidney, the left appearing to be normal.

Ascending urography was not possible owing to severe impassible urethral stricture which required suprapubic cystostomy.

He was transferred to Robroyston Sanatorium and on 25.10.54 treatment with Streptomycin and P.A.S. was started.

Aortography on 24.11.54 was performed to determine the condition of the right kidney.

The arteriogram showed a normal blood supply and pattern of the left kidney. No vascularity could be seen on

the right side. (Not illustrated.)

Operation.

Right nephrectomy was performed on 8.12.54. (A.J.) The kidney was enlarged and grossly infected with tuberculosis. The pedicle was greatly reduced in size and appeared to consist mainly of fibrous tissue.

Angiography in this case was of no value from a tuberculosis diagnostic angle. It did provide confirmatory evidence of absolute non-function shown on excretion urography when further information by retrograde pyelography was not possible. Further it gave reassurance regarding the state of the remaining kidney.

Case (99) R.B. Male aged 34.

History.

This patient had suffered from genito-urinary tuberculosis since 1941 when epididymectomy had been carried out. He remained reasonably well until June, 1954 when he suffered persistent frequency of micturition. He was referred for examination on 27.7.54.

Urological Investigation.

Cystoscopy on 27.7.54 was not satisfactory owing to bladder spasm. The urine report of the specimen obtained showed it to be positive for tuberculosis. He was admitted

to Robroyston Sanatorium for treatment.

Excretion urography on 12.8.54 (Fig. 164) shows poor definition especially on the right side. No detail is shown of the lower major calyx group in the right kidney. There is erosion of the lower calyx of the left kidney the outline of the upper calyces being indeterminate and part of the middle group obliterated.

Attempts at ascending urography to clarify the condition all failed.

Treatment with P.A.S. and Isoniazid was started on 7.8.54.

Aortography was performed on 24.11.54.

The arteriogram (Fig. 165) shows a double blood supply to the left kidney. The major branches show an abrupt termination noticeably in the middle and lower parts of the kidney. On the right side there is gross vascular deficiency to the lower part of the kidney. There is considerable overlay from the mesenteric branches.

The nephrogram (Fig. 166) confirms these findings. The left kidney is enlarged, the parenchymal outline being irregular and suggestive of "bossing". Definite areas of translucency corresponding to the vascular termination and the urographic appearances were present.

The right kidney was also irregular in outline little functioning parenchyma being present in the lower half.

No operative treatment was performed but further chemotherapy was given.

In this case angiography gave additional information to that supplied by excretion urography alone. It suggested that the tuberculous process was more advanced in each kidney.

Case (100) J.H. Male aged 31.

History.

This man was admitted to Robroyston Sanatorium on 3.4.55. He had suffered from urinary frequency for the previous two years. There had been one transient episode of haematuria, a year ago.

He was found to have tuberculous involvement of the left epididymis, vesicle and prostate.

The urine was positive for M. tuberculosis. The blood pressure was 170/105 mm./Hg.

Urological Investigation.

Excretion urography on 14.4.55 (Fig. 167) shows no function of the left kidney. On the right side there is dilatation of the calyces and ureter.

Attempts at ascending urography failed on each side.

Treatment with P.A.S. and Isoniazid started on 25.5.55.

Aortography was done on 30.5.55.

The arteriogram (Fig. 168) shows the left renal artery to be of moderately good calibre at its origin. There is a rapid decrease in size and it ends as two small terminal branches, the total effective renal vascularity being very poor.

On the right side there appear to be four renal vessels, only the vascularity of the upper vessels being demonstrated. There is some thinning and displacement typical of space-occupying lesions and corresponding to the dilated calyces.

No operative treatment was performed.

Angiography suggests advanced disease affecting the whole of the left kidney and lower part of the right.

Case (101) I.K. Female aged 43.

History.

This woman was referred to the Urological Department on 29.10.54 for check examination of the upper urinary tract.

In November, 1952, she had been treated in another hospital for renal tuberculosis affecting the right kidney. Streptomycin and P.A.S. had been given continually for five months.

Urological Investigation.

Excretion urography on 29.10.54 showed no calcification. The right renal pelvis was dilated and all

the calyces were clubbed. No function was seen on the left side.

Cystoscopy on 9.11.54 showed no abnormality the bladder capacity being normal. A catheter was passed up the left ureter a distance of 10 cm. but could not be made to pass further. The right ureter was catheterised to 23 cm.

Ascending urography (Fig. 169) confirmed the previous findings. There is fullness of the right renal pelvis with clubbing of all the calyces. On the left side no dye has ascended beyond the point of the catheter.

Aortography was done on 19.11.54. The arteriogram showed considerable overlay from other aortic branches. There was a good renal artery on the right side, the major divisions being of reasonable calibre. The cortical fanning was poor especially in the lower half of the kidney. The left renal artery was greatly diminished in size and the terminal branches were elongated and attenuated.

The nephrogram (Fig. 170) is quite instructive. The right kidney shadow is not regular, there being broadening across the midzone and tapering at the lower pole. The left nephrogram shows gross irregularity and bossing of the parenchyma suggestive of advanced disease on that side. The density is uneven, there being numerous avascular areas present.

Operation.

The left kidney was removed on 16.2.55. (A.J.)

It was found to be grossly infected with tuberculosis.

In this case angiography contributed a little further information. It suggested that the disease was more advanced than could be proved by urography.

Case (102) T.W. Male aged 46.

History.

This patient had been under treatment for genito-urinary tuberculosis since 1941. A tuberculous urethral stricture developed in 1951.

Urological Investigation.

Excretion urography on 30.9.54 showed marked hydronephrosis with poor function on the right side. The left kidney was represented by a calcified mass and no function could be seen.

Ascending urography was not possible owing to the urethral stricture.

Treatment with P.A.S. and Isoniazid started on 4.10.54.

Aortography was carried out on 29.12.54. The arteriogram (Fig. 171) shows no blood supply to the calcified left kidney, the renal artery being represented by a short stump from the aorta. On the right side there is duplication of the renal artery but the calibre of each vessel is small. The divisions and branches are thin and attenuated and resemble

the appearances found in hydronephrosis.

Little appreciable nephrogram effect was shown.

The angiographic findings were of total irrevocable loss of function on the left side and advanced hydronephrosis of the right kidney. No specific causes for the latter could be given.

This patient's condition suddenly deteriorated and he died a week later. Post-mortem examination showed advanced bilateral tuberculous pyonephrosis and a large infiltrating carcinoma of the bladder.

Angiography merely confirmed that the disease had progressed to an advanced stage.

Case (103) J.O. Male aged 21.

History.

This patient was admitted to Robroyston Sanatorium on 15.6.53 with bilateral active pulmonary tuberculosis.

After treatment for the pulmonary lesion the urinary tract was examined.

Urological Investigation.

Excretion urography on 21.9.53 showed a calcified mass in the right renal area with no function. The left kidney showed a full pelvis and elongated upper calyx with filling defects associated with the middle and lower calyx

groups.

Ascending urography on 24.9.53, 12.1.54 and 6.4.54 (Fig. 172) confirmed lesions affecting the middle and lower calyces of the left kidney. The right ureter could not be catheterised.

Aortography was performed on 21.12.54, the patient having had two six month courses of Isoniazid and Streptomycin.

The arteriogram (Fig. 173) shows no vascularity at all on the calcified right side, the origin of the artery being overlaid by the superior mesenteric vessel. On the left side there is a good main supply. The vascularity of the middle and lower thirds is good and no evidence of fibrosis may be seen. The interlobar branches are thick and two small areas of calcification are present.

The nephrogram appeared somewhat mottled but this appearance was not confined to the affected area.

Angiography did not afford any additional information in this patient's case.

Case (104) W.G. Male aged 25.

History.

This man was seen at the Royal Infirmary on 15.2.55 complaining of a swelling in the right scrotum. On examination he was considered to have a tuberculous epididymis

with prostatic and vesical involvement.

The urine was positive for tuberculosis.

Urological Investigation.

Excretion urography on 15.2.55 showed no function of the right kidney. The left appeared to be normal.

Treatment with Streptomycin and P.A.S. was started on 22.2.55 in Robroyston.

Aortography was performed on 16.3.55.

The arteriogram (Fig. 174) shows a double blood supply to the right kidney. Whilst these main vessels are of reasonable calibre the main divisions are narrow, short and have an abrupt ending with no cortical branching. The effective renal vascularity is very poor. On the left side the vascularity appears to be normal.

No nephrogram was obtained on the right side.

Operation.

Right nephrectomy was performed on 31.3.55. (A.J.)

The presence of two arteries was confirmed. The kidney was a large tuberculous one with an abscess cavity at the upper pole.

Angiography proved of no diagnostic value in this case as was to be expected in a non-functioning organ.

It did, however, show irrevocable loss of function and, from the operative view, the presence of two renal

arteries.

Such information is useful because not infrequently tuberculous kidneys are adherent and difficult to remove. The knowledge of the presence of accessory main vessels may prevent serious haemorrhage during mobilisation.

Case (105) J.M. Male aged 31.

History.

This man had a long history of pulmonary and bone tuberculosis since 1944. The urine was positive for tuberculosis in 1950 and he had received several forms of treatment at intervals since then, including Streptomycin and P.A.S.

Urological Investigation.

Excretion urography on 17.8.54 and ascending pyelography on 30.9.54 showed a small defect still present at the upper minor calyx of the right kidney.

Treatment with P.A.S. and Isoniazid was started on 9.10.54.

Aortography was performed on 2.1.55.

The film (Fig. 175) is not entirely satisfactory as slight respiratory movement occurred. The only change in the arteriogram, in the region of the lesion, consists of abrupt endings to the interlobar vessels of the right upper pole. Beyond these cortical vascularity is absent.

The nephrogram showed little appreciable change from normal.

Operation.

Partial nephrectomy, (resection of the right upper calyx) was carried out on 9.2.55. (A.J.)

In this case the arteriogram was not of good quality and although there appeared to be vascular changes in the right upper pole these were not considered to be diagnostic. These changes, however, did suggest that the process had affected a greater area of kidney substance than was shown by the small pyelographic defect.

Case (106) J.T. Male aged 53.

History.

This man was admitted to Robroyston Sanatorium on 19.7.55. He complained of increasing frequency of micturition over the past year resulting in the necessity to void every hour. In addition, he had some pain in the right side.

Urological Investigation.

Gross spinal deformity due to Pott's disease was present, kyphosis being very marked.

The urine was positive for M. tuberculosis.

Excretion urography was unsatisfactory and failed to outline either kidney.

Bilateral ascending urography on 20.7.55 suggested the possibility of tuberculous lesions affecting the minor calyces of the right kidney.

Treatment with Streptomycin and P.A.S. was started on 25.7.55.

Aortography was performed on 31.8.55.

The arteriogram (Fig. 176) shows gross spinal deformity and deviation of the aorta.

The renal vasculature is not clear and has afforded no additional information. Although puncture was effected easily and "first time" it is doubtful if aortography should be done under such conditions of skeletal deformity with consequent aortic displacement. Whilst, as has been shown, puncture can be performed, the overlay from bony structures and displaced vessels may render interpretation impossible.

Case (107) D.C. Male aged 28.

History.

This patient was admitted to Robroyston Sanatorium on 31.8.55. He complained of constant dull pain in the right loin which had been present for the past few months. There had been no frequency or haematuria. The urine contained M. tuberculosis.

Urological Investigation.

No significant abnormality was found. The presence

of M. tuberculosis in the urine was confirmed.

Excretion urography on 4.9.55 showed poor concentration and detail was insufficient to permit a diagnosis.

Cystoscopy on 5.9.55 showed no bladder abnormality other than small ureteric openings. Ascending urography showed a small lesion in the upper calyx of the right kidney.

Aortography was performed on 7.9.55 before starting treatment with Streptomycin and P.A.S.

The arteriogram (Fig. 177) shows no change in the vascular pattern and no diagnosis of ischaemia in the affected area may be determined.

The nephrograms appeared to be quite normal.

Case (108) W.S. Male aged 22.

History.

This patient was admitted to Robroyston Sanatorium on 1.3.55. He had complained of left-sided pain associated with frequency of micturition and the urine had been found to contain M. tuberculosis.

Urological Investigation.

Apart from some tenderness in the left loin the clinical findings were essentially normal. The urine was confirmed to be positive for tuberculosis.

Excretion urography on 19.4.55 suggested the possibility of a tuberculous focus in the middle and upper

calyces of the left kidney.

Ascending urography on 14.6.55 showed the right kidney to be normal and a small lesion of the ulcero-cavernous type associated with the middle and upper left calyces.

Treatment with Streptomycin and P.A.S. was started on 6.7.55.

Aortography was performed on 24.8.55.

The arteriogram (Fig. 178) shows rather poor definition due to delay in exposure of the first film. There is some splenic overlay but there is nothing diagnostic of tuberculosis or ischaemia to be made out.

This was confirmed on the nephrogram.

These two cases, in which a small lesion not definitely shown on excretion urography but proved on retrograde pyelography, illustrate the limitations of angiography in this condition. No indication of the site, size or type of tuberculous infection was afforded, either on the arteriogram or nephrogram.

Case (109) J.H. Female aged 28.

History.

This patient was admitted to Robroyston Sanatorium on 29.8.55. The urine had been found to be positive for tuberculosis in another hospital.

Urological Investigation.

Excretion urography on 1.9.55, suggested dilatation of the left calyces, the right being normal.

Cystoscopy on 1.9.55 showed no lesion present in the bladder. Ascending urography showed the right kidney to be normal while on the left side marked cavitation affecting all areas was present.

Aortography was performed on 7.9.55 before starting chemotherapy with P.A.S. and Isoniazid.

The arteriogram (Fig. 179) shows the right renal vasculature to be normal and compact. On the left side the kidney is somewhat larger and the divisions and branches are more separated. There is, however, no evidence of any abrupt ending of the vessels and no ischaemic area shown.

This was confirmed on the nephrogram.

The angiographic appearances in this case, whilst reflecting the pathological changes of calyceal dilatation, were in no way diagnostic of the underlying tuberculous lesions.

SUMMARY AND CONCLUSIONS.

The findings in this small number of patients with renal tuberculosis have not been consistent. Allowance must be made for the different types of lesion varying between the minimal calyceal erosion and the gross non-functioning tuberculous pyonephrosis. Further, the effect of chemotherapy during the interval between the urographic and angiographic examinations cannot be discounted.

The claims submitted by Weyde of the superiority of angiography over urography in demonstrating the extent of the lesion have not been confirmed, except in three cases. (Cases 97,99 and 105.)

In three cases (Cases 106,107 and 108) no angiographic changes of significance were seen, although the lesions had been shown on urography. In Case (103) the spinal deformity masked the renal vasculature.

In the remaining eight cases, abnormal vascular patterns, equivalent to the urographic and pathological changes were shown.

The diagnosis of renal tuberculosis cannot be made by angiography alone. Even where vascular abnormality is shown, such as atrophy of the vessels and translucency of certain areas, these cannot be distinguished from renal ischaemia due to any other form of infection such as

pyelonephritis.

A normal renal vascularity may be shown in a kidney with early calyceal erosion demonstrable on urography.

Whilst angiography is not diagnostic it may afford confirmatory information regarding the extent of the lesion. This is particularly so in the case of the nephrogram which will demonstrate the presence of bossing.

It is felt that the two main contributions which angiography offers in the management of renal tuberculosis are not related to the specificity of the condition. They are:

(1) The assessment of the kidney where no function is shown on excretion urography and catheterisation of the ureter is not possible.

(2) The demonstration of the blood supply where partial nephrectomy is contemplated. This is of importance and may contribute to the avoidance of urinary fistula formation or secondary haemorrhage.

Whilst the above results have proved disappointing in the assessment of the extent of the lesion, it is considered that before a full appreciation can be made, further investigation should be undertaken along the following lines:-

(1) Angiography should be carried out within a short

time of the urographic diagnosis and before the institution of any form of treatment.

(2) This should be repeated after chemotherapy so that the results may be properly correlated.

(3) The cases should be grouped according to the type of lesion and the form of chemotherapy.

RENAL HYPOPLASIA.

Reduction in the size of one kidney may occur as a congenital abnormality or it may follow ureteral obstruction, disease of the renal arteries or a chronic inflammatory process.

The distinction between the congenital and acquired type is not always possible on urographic and histological examination.

The importance of the condition lies in its recognition. The affected kidney may require removal because of urinary symptoms referable to it, or its association with hypertension.

In the event of the contra-lateral kidney requiring treatment it must be regarded as a solitary organ. In spite of apparently satisfactory function of an atrophic kidney it is incapable of undergoing compensatory hypertrophy. (Albarran, 1905)

The diagnosis is made on radiographic examination.

In the present series, eight patients with marked hypoplasia of one kidney have been investigated by angiography.

One example (Case 116) secondary to ureteral obstruction, is described in the section dealing with post-operative function. Four other cases (133,134,135 and 137) were associated with hypertension and are detailed under that

heading.

In addition one other case of obstruction in the main renal artery leading to slight hypoplasia is described in association with hypertension. (Case 138)

Congenital Hypoplasia.

The following case illustrates this type. Although infection of the kidney existed and may have played some part in the atrophy, a congenital factor was also present.

Case (110) M.W. Female aged 25.

History.

This patient was first seen on 4.2.55 as an outpatient. She complained of almost constant pain in the right loin of four years duration. The pain was occasionally acute and extended to the groin. There was associated urinary frequency N/D, 1-2/½-1 hr. Haematuria had not been noted but the urine was cloudy at times.

Urological Investigation.

There was tenderness in the right renal angle but the kidney was not palpable.

Apart from the scars of previous operations for the relief of intestinal obstruction and appendicitis, no other abnormality was found. The blood pressure was 110/70 mm./Hg.

Urological Investigation.

Excretion urography on 4.2.55 showed no evidence of dye on the right side. The left kidney concentrated moderately well and showed apparent flattening of the minor calyces.

Urine examination showed infection with B. Coli.

Cystoscopy on 7.2.55 showed no bladder abnormality and both ureters were catheterised to 25 cm.

Ascending urography showed no abnormality of the left kidney. The right renal pelvis was very small and only two tiny calyces arose directly from it. The organ was incompletely rotated, the pelvis and calyces pointing forwards. These appearances strongly suggested a congenital hypoplasia.

She was admitted to hospital with a view to operation.

Aortography was done on 11.3.55. This shows (Fig. 180) a normal left renal vascularity. On the affected side, the total renal blood supply is confined to a tiny vessel with two major divisions, the whole constituting no more than the size of a lumbar artery seen above it. No nephrogram effect was produced on the right side. (Fig. 181)

The inability of a hypoplasia such as this to undergo compensatory hypertrophy and undertake the total renal function is clearly confirmed.

Operation.

Right nephrectomy (W.B.S.) was carried out on 5.1.55, a small kidney 5 x 2 cm. in size being found. The pedicle appeared to consist of a thin fibrous strand and no pulsation was felt.

Nephrectomy was carried out. Histological section showed areas of mild chronic pyelonephritis.

Hypoplasia secondary to Pyelonephritis.

The following two cases are considered to be illustrative of this type of hypoplasia.

Case (111) L.M. Female aged 38.

History.

This woman was first seen as an outpatient on 12.2.52. She had suffered three attacks of urinary infection over the previous nine months. These attacks were associated with urinary frequency, dysuria and pain in the left loin. Temporary relief was obtained from sulphonamide therapy.

Urological Investigation.

Excretion urography on 12.2.52 showed the right kidney to be normal. The left kidney appeared to be slightly smaller than normal, no lower calyx being shown. She had a

definite urinary infection due to enterococci.

Cystoscopy on 18.2.52 showed cystitis cystica.

She was seen at intervals until 7.9.53. During this time she had undergone several examinations of the urine, the bladder and X-Rays of the urinary tract. The latter showed the left kidney progressively decreasing in size. The bouts of urinary infection had been controlled by various urinary antiseptics.

Following a severe recurrence of symptoms during which she was treated in another hospital for eight weeks, she reported back for further examination on 6.7.54.

Excretion and ascending urography showed the left kidney to be much smaller and functioning poorly.

Cystoscopy showed a degree of cystitis, the urine containing B. Coli. The blood pressure was 140/85 mm./Hg.

In view of the renewed chronic infection, nephrectomy was advised.

Aortography on 27.8.54 was performed to determine the degree of renal vascular impairment.

The arteriogram (Fig. 182) shows the right renal artery to be normal in size and distribution. The left artery is slightly smaller but runs a very vertical course upwards. The branches are thin and whilst they divide equally and regularly they resemble more a half-opened fan. The whole vascularity appears to be almost wedge-shaped.

It is interesting to note the early division of the splenic artery into two main branches and the course of the hepatic artery which runs to the left of the midline.

Operation.

At operation on 31.8.54 (W.B.S.) a small high-lying kidney was found. It was judged to be half the normal size and showed the surface irregularity of pyelonephritis.

Histological examination of the organ, which weighed 80 gm., showed chronic pyelonephritis. Early hypertensive vascular changes were present.

This patient has remained free from symptoms and infection for the past year.

Case (112) A.W. Female aged 36.

History

This woman was admitted to a Surgical Unit as a case of acute appendicitis. Clinical examination did not confirm this diagnosis but suggested that the right-sided pain was due to a lesion of the urinary tract. X-Ray examination showed what appeared to be two stones in the right renal area.

She was referred for urological examination on 9.9.54.

Urological Investigation.

Apart from tenderness in the right loin no clinical abnormality was found. The blood pressure was 120/80 mm./Hg.

Excretion urography on 9.9.54 showed little apparent concentration of the dye on the right side. Two stones were present but the exact position of these was not shown. The left kidney appeared somewhat enlarged, the pelvis being of the full type but not truly hydronephrotic.

Ascending pyelography on 10.9.54 confirmed the presence of the stones lying in the upper and lower calyces respectively. The pelvis was greatly reduced in size and there was a definite constriction amounting to a cut-off at the uretero-pelvic junction.

The parenchymal outline of the kidney was not seen.

Aortography on 13.9.54 shows (Fig. 183) a normal left renal blood supply. The early nephrogram phase can also be seen, the kidney being of a large size. On the right side the stones are demonstrated and the blood supply is almost non-existent.

Careful examination, however, shows the origin of an upper right renal artery to lie at the lower border of the 1st lumbar vertebra. It is partly obscured by a lumbar artery but the line of the aorta clearly shows the origin of the renal vessel. Beyond this point the artery is extremely narrow and after division peters out as tiny distracted vessels with no resemblance to the usual renal "fanning". There is an additional or accessory vessel of similar calibre arising from the aorta at the level of the upper border of

the 2nd lumbar vertebra.

The lower accessory vessel, however, was not responsible for the uretero-pelvic obstruction as comparison of the arteriogram and ascending pyelogram showed clearly that this vessel lay well above the uretero-pelvic junction.

The total vascularity did not permit any nephrogram effect.

Operation.

On 14.9.54 the right kidney was removed. (W.B.S.) It was found to be small and grossly hydronephrotic, weighing only 35 gm. The presence of two arteries was confirmed, each being extremely narrowed and fibrosed.

Histological section showed chronic pyelonephritis. In places the kidney was reduced to a thin rind of fibrous tissue containing a few dilated and atrophic tubules.

SUMMARY AND CONCLUSIONS.

The angiographic changes which occur in hypoplasia reflect the reduction in size of the kidney by the reduction in the total vascularity. This affects not only the small branches but also the divisions and main renal artery.

In the majority, the arteriogram shows a small thin

main vessel with tiny narrowed divisions. Where the obliterative process is more advanced, only the stump of the renal artery may remain patent as in Case (116)

Where the artery is extremely small, it is important to distinguish it from a lumbar artery by careful scrutiny of its origin, course and ending.

A nephrogram effect depends on the amount of functioning cortex and where this is absent no parenchymal outline will be visible.

A number of hypoplastic kidneys show no dye concentration on excretion urography and not infrequently such cases are difficult to catheterise. (Smith, Rush and Evans. 1951)

Angiography may be the only method, short of operation, by which a diagnosis can be made.

POST-OPERATIVE FUNCTION.

In the majority of cases described under the various specific conditions, angiography has been used to demonstrate the anatomical outline of the arteries, to define the renal mass and to assess renal function before operation.

The procedure, however, may be used with equal effect after operation.

The following four cases were investigated by aortography after operation when the usual methods could not be used or failed to assess adequately the function of the kidneys.

Two of these cases, uretero-colic anastomosis, are of particular interest in that angiography has not previously been used in such circumstances.

Uretero-colic anastomosis may be followed by the development of certain blood electrolyte changes in the form of hyperchloraemic acidosis.

In a collective review of 201 patients who had this operation performed for various conditions, malignant and otherwise, 40.3% showed evidence of hyperchloraemic acidosis at some stage. (Jacobs and Stirling, 1953)

The recognition of the occurrence of such serious biochemical upset requires adequate post-operative investigation. In most urological centres it is now the

practice to perform excretion urography and blood electrolyte estimations at regular intervals.

In the two patients investigated neither of these examinations eventually proved possible as no suitable vein could be found in spite of repeated attempts at venepuncture.

Case (113) M.R. Female aged 59.

History.

This patient had a vesico-vaginal fistula following a gynaecological operation in 1935. She was found to have a congenital solitary right kidney and on 18.1.45 a right uretero-colic anastomosis was performed. (A.J.)

Subsequent examinations were satisfactory but since 1951 (a period of three years) no information regarding the state of the right kidney or the blood electrolytes had been possible through failure to carry out a satisfactory venepuncture.

Ascending urography was of course impossible in such a case.

It was decided to employ aortography on 5.11.54.

The arteriogram (Fig. 184) shows the needle placed opposite the origin of the right renal artery. This vessel is long and has a good normal intra-renal pattern. There is no evidence of a left renal artery, the aortic wall being smooth and unbroken in conformity with congenital absence of

a kidney on that side.

The nephrogram showed an excellent parenchymal shadow, the density being good. The organ is somewhat elongated but not dilated. Later films were taken to obtain the late excretory phase which showed satisfactory condensation of the dye with no abnormality of the collecting system.

The opportunity was taken of collecting blood for electrolyte estimations, these proving to be normal.

Case (114) H.W. Female aged 41.

History.

This woman had a tuberculous left kidney removed in 1940. (A.J.)

The remaining right ureter was implanted into the colon in 1948. (A.J.)

She remained well until 1951 when she was acutely ill with pyelonephritis and transient anuria. She made a good recovery but eventually it did not prove possible to carry out venepuncture for urography or blood chemistry estimations.

Aortography was performed on 29.10.54.

The arteriogram (Fig. 185) shows a good main blood supply to the right kidney. The cortical branching is excellent except towards the upper pole. This film is a late arteriogram phase and the parenchymal outline of a large

kidney may be seen.

Later films showed some degree of dilatation of all the calyces, this being more marked in the upper major group.

Blood was taken from the aorta for electrolyte estimations and when under the anaesthetic it was found possible to obtain venous blood. The relative estimations are given below:-

	Venous	Arterial
Alkali Reserve	24.0 m.Eq.	23.0 m.Eq.
Chloride	103.8 "	104.5 "
Sodium	156.0 "	157.0 "
Potassium	4.6 "	3.7 "
Urea	35.0 mgm/%	30.0 mgm/%

The only significant difference lies in the Potassium estimation.

It was not known whether there was normally any appreciable difference between the potassium levels of arterial and venous blood. Biochemical examinations were therefore performed on a further six patients, submitted to aortic puncture, and in these no significant difference between any of the electrolytes was found. It is considered that in this case lysis had occurred in the arterial specimen.

The third patient was one on whom renal operations

had been previously performed.

Subsequent urography, both excretion and ascending, had not proved satisfactory.

Case (115) E.W. Female aged 33.

History.

This patient was re-admitted on 1.8.55 for investigation of pain in the left loin.

She had undergone a plastic repair (Von Lichtenberg II) for hydronephrosis of the left kidney in 1946. (A.J.)

In 1947, nephropexy (Thomson-Walker) had been performed for a mobile right kidney. (A.J.)

Following these operations she had felt well until 1952. She had an attack of severe pain in the left loin at that time and these bouts of pain had continued and become more frequent before admission. She had occasional haematuria and dysuria.

Urological Investigation.

Excretion urography on 3.8.55 showed good concentration from the right kidney, the pelvis of which was rather full. The left kidney showed only some very faint blobs of dye.

Cystoscopy on 5.8.55 showed no abnormality and the left ureter was catheterised to 25 cm. Ascending pyelography was unsatisfactory, only one rounded shadow of dye being seen.

In view of the unsatisfactory results of urography it was decided to use angiography to assess the state of the left kidney.

Aortography was performed on 8.8.55.

The arteriogram (Fig. 186) shows a normal supply to the right kidney. The affected side shows considerable diminution of vascularity. The main artery is almost one-third normal size and has one branch arising from it running to the lower part of the kidney. This vessel is almost certainly the aberrant one noted at the original operation as crossing and obstructing the uretero-pelvic junction.

The terminal branches are very few and there is almost complete absence of cortical fanning. No appreciable nephrogram effect was obtained thus denoting considerable reduction in effective renal function.

The symptoms of left-sided pain subsided and no operation was performed. Nothing short of nephrectomy would be worth while in this case.

The last patient was one in whom obstruction of the kidney had occurred due to an impacted stone in the ureter which required operative removal.

Case (116) J.D. Female aged 27.

History.

This patient had an attack of pain in the right side and was sent to hospital on 6.9.53 as a case of acute appendicitis. Clinical examination did not confirm this diagnosis and she was admitted for medical observation. X-Ray examination showed no function of the right kidney. The blood pressure was 115/80 mm./Hg. She was referred for further examination of the urinary tract.

Urological Investigation.

Right ascending pyelography was attempted on 11.9.53. The bladder appearances were normal on cystoscopy but a ureteric catheter was obstructed 6 cm. from the orifice of the right ureter. X-Ray showed the catheter in contact with a stone and no dye had ascended beyond that point. There was fusion of the third and fourth lumbar vertebrae.

In view of the absence of function from the right kidney and the complete obstruction of the ureter by the stone operative treatment was undertaken. Right uretero-lithotomy (A.J.) was performed on 16.9.53.

Following dismissal from hospital after an uneventful convalescence, excretion urography was repeated on 27.10.53 to determine the state of the right kidney. This again showed no obvious excretion of the dye on the right side, the left kidney being normal in function and appearance.

A repeat ascending pyelogram was attempted on 2.11.53. The catheter could not be made to pass beyond the site of the previous obstruction nor could any dye be injected above this point.

After an interval these examinations were repeated. On 12.1.54, excretion urography again failed to demonstrate any function of the right kidney and a further attempt at right ascending pyelography failed, neither the catheter nor the dye extending above a point 6 cm. from the vesical orifice.

These investigations did not afford any information regarding the state of the right kidney and in view of her symptoms of intermittent pain in the right loin it was decided to perform aortography to see if this would elucidate the problem.

Translumbar aortography was done on 19.2.54. The appearances proved interesting and instructive. The arteriogram (Fig. 187) shows a normal but somewhat hypertrophied left renal blood supply. The right renal artery shows a tapering obliteration a short distance from its origin. There is complete absence of blood flow beyond this point.

This appearance is not quite typical of the changes seen in hydronephrosis. The diagnosis was made of atrophy of the kidney secondary to complete ureteric obstruction and obliterative endarteritis extending along the main artery.

This vascular deficiency did not produce any nephrogram effect.

Operation.

Right nephrectomy (W.B.S.) was performed on 23.2.54.

The arteriographic diagnosis was confirmed, a very small kidney measuring 2 x 1 cm. being removed. The pedicle consisted only of a fibrous strand, no pulsation being felt. The histological examination showed marked endarteritis present.

The value of renal angiography in this case was considerable. Urographic examination, whilst demonstrating the absence of function, gave no further indication of the state of the kidney. Arteriography confirmed beyond all doubt that recovery of function was impossible and gave a specific diagnosis of the renal state.

In such cases it is extremely difficult to determine at what stage recovery of function of a kidney may occur when it has been totally obstructed. This has not been determined in the human although animal experiments suggest that in them recovery of function is unlikely after a period of three weeks.

It may well be that arteriography will contribute valuable information in this sphere.

SUMMARY AND CONCLUSIONS.

Angiography has been used in four cases in which, following operation, the usual urographic methods failed. In each case it provided all the necessary information.

In addition, it gave a diagnosis in the last patient. (Case 116)

In such special circumstances it is a valuable additional method of investigation.

One important factor must be recognised in the assessment of renal function by angiography, whether before or after operation. Where comparative estimations are made, these must depend on an approximately equal quantity and concentration of dye entering each kidney.

Where the needle point lies close to the origin of the right renal artery, a greater amount of dye may enter that vessel. This may be of little importance in judging the main arterial supply but will undoubtedly delineate more of the finer branches and produce a denser nephrogram and excretion urogram.

Whilst such an event cannot be excluded in every case, the technique of rapid injection, with the needle point above or below the origin, is sufficient for all practical purposes of renal appraisement.

RENAL ARTERY ANEURYSM.

Aneurysm of the renal artery is a rare observation both clinically and at autopsy. Up to 1955 there have been 93 reported cases of whom 17 only had a correct positive diagnosis before surgery or post-mortem examination.

In one case the aneurysm was found to be part of a generalised peri-arteritis nodosa.

The symptomatology is extremely variable and not at all specific.

Up to date the radiographic findings have been described as calcification, ringlike in appearance, near the kidney. The differential diagnosis is from calcified cysts of the kidney or spleen, calcified abscesses or haematoma, renal calculi, gallstones, calcified neoplasms and lymph nodes.

The only certain method of determining the presence of a renal aneurysm is by the demonstration of filling of the lumen with dye. This can only be done by arteriography.

One such case has been published recently by Begner, (1955).

This was a woman of 49, whose complaint was of pain in the back and occasional gastric discomfort.

Clinical examination yielded tenderness in the left hypochondrium and a mass in the region of the left kidney.

Excretion urography showed a ringlike shadow closely

associated with the upper medial aspect of the left kidney and causing a smooth compression defect of the renal pelvis.

A provisional diagnosis of aneurysm was made but it was decided to employ aortography in an attempt to fill the shadow with dye and so make certain the diagnosis.

This was successfully done and proved later at operation.

The only other reference to the demonstration of aneurysm by arteriography is that of Burns and Hendon (1954) of which mention is made later in the review of literature pertaining to hypertension.

One case of renal artery aneurysm has been investigated in this series, the arteriographic findings being equally conclusive.

Case (117) M.B. Female aged 60.

History.

This patient was admitted to a Surgical Unit for observation and investigation. Her only complaint was of occasional attacks of nausea and vomiting. She had no pain and had no symptoms referable to the urinary tract.

Investigation was essentially negative but after X-Ray examination of the gall bladder a faint ring shadow was seen in the region of the hilum of each kidney. The blood

pressure was 190/95 mm./Hg.

The possibility of renal aneurysm was considered.

The patient was referred for further investigation including arteriography.

Urological Investigation.

Clinical examination on 16.1.55 showed no abnormality of the genito-urinary system. There was no renal tenderness or enlargement. No mass was palpable nor was any bruit audible on the left side.

Excretion urography was carried out on the same date to ascertain the pelvic and calyceal pattern. This was quite normal. The faint ringlike shadows previously noted were present in all the films. On the left side, the shadow overlay the 12th rib at a distance just beyond the tip of the lumbar transverse processes. That on the right side was higher and more lateral.

Aortography was carried out on 21.1.55.

The arteriogram (Fig. 188) clearly shows the presence of an aneurysm of the left main renal artery.

The saccular dilatation arises from the artery at or near its point of division outside the renal sinus. It is well-filled with the dye and has a diameter of about 2 cm. Its position medial to the upper third of the kidney would not cause any pressure deformity of the pelvis or calyces.

The total vascularity of the left kidney beyond the

aneurysm is but little affected although it is not quite as good as that of the right kidney. This was confirmed on the nephrogram.

Examination of the right renal blood supply, however, shows small round dilatations affecting two of the main branches. The ringlike shadow on this side has not filled with dye and presumably the lumen is occluded by thrombus.

Similar but much smaller dilatations are also present in some of the terminal branches of the splenic and hepatic arteries.

These findings suggest that the larger renal aneurysms are part of a generalised peri-arteritis nodosa affecting other vessels.

Histological examination of a muscle biopsy was not available.

In view of the presence of multiple aneurysms and the paucity of symptoms, none of which was referable to the kidney, operative treatment was not considered necessary or advisable.

The patient has remained well since.

SUMMARY AND CONCLUSIONS.

The advantages of arteriography in the diagnosis of aneurysm of the renal artery are obvious and it should form an essential part of the investigation in such cases.

The demonstration of filling of the sac is conclusive and determines the size and shape of the dilatation and its relation to the kidney. It may also show, as in this case, saccular aneurysm of other vessels not suspected on ordinary radiographic examination.

It is equally valuable in the exclusion of suspected aneurysm as in Case (132, Fig. 203) where the ringlike shadow was shown to be unconnected with the renal arteries.

Where thrombosis has occurred within the sac dye filling may not be complete. An indication, however, will be given of the close relationship between the aneurysm and the affected vessel.

RENAL TRAUMA.

Simple injury to the kidney is not very common and an adequate assessment of the damage and form of treatment can be made on clinical and urographic examinations. It is unlikely that aortography will furnish further information in the early stages following injury and its use at that time does not appear to be justifiable. Where information is required at a later date regarding ischaemia of any part of the kidney it may prove useful.

The following case is an example of the use of angiography in these circumstances.

Case (118) P.M. Male aged 14.

History.

This boy was admitted to a Surgical Unit in July 1954, following an injury to the right kidney as a result of a fall. At that time haematuria lasted some 10 days but no operative treatment was undertaken.

An excretion urogram 14 days after the injury was reported as showing "damage to the right kidney." Unfortunately these films are not available and I am unable to state the site and extent of the damage.

Six months later he was admitted to another Surgical

Unit complaining of right-sided abdominal pain associated with headaches. No significant clinical abnormality was found and the blood pressure was 110/75 mm./Hg.

Urological Investigation.

In order to obtain the maximum anatomical detail ascending pyelography was performed on 4.3.55. This showed no appreciable abnormality of the pelvis or calyces and no evidence of any damage.

Aortography was performed on 11.3.55.

The arteriogram (Fig. 189) shows the main vessel to be of normal calibre. Within the kidney the branches appear to be confined mainly to the middle segment and the lack of cortical supply is more marked in the upper pole.

The nephrogram showed some decreased density compared with the left side but no definite demarcated ischaemic area could be made out.

In the absence of this and any appreciable hypertension no surgical treatment was undertaken.

SUMMARY AND CONCLUSIONS.

The use of angiography, whilst probably not justifiable in the early stages of renal injury may be valuable after clinical recovery in demonstrating vascular deficiency of the affected renal parenchyma.

ADRENAL GLANDS.

The diagnosis of lesions affecting the adrenal glands is never easy. It is no part of this thesis to discuss the clinical and biochemical findings of the various adrenal syndromes. Suffice it to say that the results of these investigations are frequently equivocal.

Radiological examinations include excretion and, if necessary, ascending urography. This will determine the presence and the position of the kidneys and may on occasion suggest the outline of an adrenal gland. Even where downward displacement of a kidney is demonstrated it is seldom possible on this examination alone to state that it is due to adrenal enlargement.

The use of air insufflation around the kidneys and adrenals may prove more helpful. The newer technique of pre-sacral retrorectal injection is superior to the older method of puncture through the loin in that it is less disturbing, affords easier and more rapid diffusion of air in the correct plane and produces simultaneous bilateral pneumograms. Nevertheless, it must be admitted that in many established adrenal lesions, especially in Cushing's syndrome, the pictures are by no means always clear or diagnostic. Indeed they may be misleading.

The main lesions affecting the adrenal glands of surgical importance comprise tumours of the medulla such as pheochromocytoma and tumours or hyperplasia of the cortex responsible for the Cushing or adrenogenital syndrome.

The size of an adrenal tumour is not directly related to the severity of the signs and symptoms which it may produce. Thus, whilst a successful pneumogram will show the size and shape of the gland it may not indicate the type of lesion in the absence of any significant enlargement.

Arteriography appeared to offer an additional method of investigating these difficult conditions.

Mention has already been made of the angiographic visualisation of small cortical tumours of the kidney which, because of their size and position, do not produce any pyelographic deformity. The appearance of the nutrient vessels and pooling in the vascular sinuses were quite diagnostic.

If similar appearances could be seen in the adrenal glands it would serve to distinguish between tumour and hyperplasia of the cortex as the causal factor in hyperactivity of the latter. Further, the production of an "adrenogram" should determine the size and shape of the gland with greater accuracy than any other radiological method.

An adrenogram is, however, dependent on the dye filling the main adrenal arteries. In this study it has been found that only in some 5% of patients has satisfactory

definition of these vessels been shown.

The infrequency with which the adrenal vascularity is defined even with good visualisation of the aorta and renal arteries may be ascribed to three main factors:

(1) The variable origin and relatively small size of the adrenal arteries.

(2) The course and haemodynamics of these vessels.

(3) The physiological alteration in the blood flow through the gland.

According to Balfour (1953) - "It is generally agreed that the administration of A.C.T.H. produces a cortical hyperaemia of the adrenal gland. This is associated with a temporary increase in the adrenal blood flow".

It is not possible to influence the first two factors responsible for poor adrenal definition but it was hoped that some effect might be produced on the last by stimulation therapy. It was therefore decided to administer adreno-corticotrophic hormone to several patients. The object of this experiment, of which there is no previous record, was to ascertain if the increased vascularity was demonstrable by arteriography. If successful, this should produce more frequent adrenograms and enable a more accurate description to be made of the normal arterial blood supply for comparison

with the abnormal. Further, it might enable comparison to be made between the normal and hyperexcretory gland.

In the first instance A.C.T.H. was given by injection - 50 mgm. 1 hour before aortography. The two patients who received this therapy showed no appreciable increase in the adrenal vasculature. It was thought that this dosage might be insufficient to produce any significant alteration in hyperaemia and accordingly 100 mgm. A.C.T.H. was given daily for four days before examination to a further six patients. In no case did there appear to be any appreciable increase in the definition of the arterial blood supply or production of adrenograms.

Several references have been made in the literature to the potential value of arteriography in adrenal disease. In many cases, however, such statements have been made on theoretical grounds and little proof has been offered of arteriography having proved diagnostic or even having been used at all.

The following references are worthy of note:-

Nelson (1942) described the findings in one case of carcinoma of the right adrenal gland.

The patient, a woman aged 29, showed the typical "adreno-genital syndrome" with marked hirsutism. Excretion urography was normal. Aortography proved diagnostic of

adrenal tumour.

The arteriogram showed a large main artery arising from the aorta. The nephrogram phase showed an adrenogram with pooling of dye. This shadow was obviously without the kidney. Adrenal neoplasm was diagnosed and at operation a large tumour weighing 720 gm. was removed.

The second case was that described by Burns and Hendon (1954). This was a boy, aged 13, with hypertension and a right-sided mass. Diagnostic tests of benzodioxane, regitine and air insufflation were not helpful. Aortography confirmed the presence of adrenal enlargement above the right kidney. In view of the clinical and arteriographic findings a diagnosis of pheochromocytoma of the right adrenal medulla was made and confirmed at operation. The interpretation of the published photographs is not easy but undoubtedly an adrenal mass can be made out.

Goodwin, Moore and Pierce (1955) in discussing the value of combined air insufflation and aortography reported two cortical and two medullary tumours diagnosed by these methods.

The first of the cortical tumours occurred in a young girl aged three who showed the adreno-genital syndrome. An area of increased vascularity without definite margins was seen in the right adrenal area. A cortical tumour 6 cm. in size was removed at operation.

The second patient was a woman of twenty-nine with Cushing's syndrome. A right adrenal cortical tumour with a hypertrophied inferior adrenal artery was shown on aortography and confirmed at operation.

The medullary tumours in the next two cases consisted of pheochromocytoma. The first patient, a man of twenty-four years, suffering from hypertension, was clinically diagnosed as such. Aortography demonstrated an indeterminate mass below the renal pedicle on the right side. The tumour, removed at operation measured 6 x 4 cm.

The second patient, a boy of eight years, was also diagnosed clinically as pheochromocytoma. An enlarged right adrenal gland was shown on aortography, performed by the method of retrograde catheterisation from the femoral artery.

The published photographs, whilst not of a high standard, do indicate enlargement of the adrenal gland in each case.

With regard to medullary tumours, Cahill (1952) has not found arteriography helpful in the diagnosis of pheochromocytoma although he does not state the number of investigations performed by this method. A similar statement is made by Whiteside (1953)

The comparative rarity of adrenal lesions accounts for the paucity of reports regarding the value of aortography

in this condition.

The opportunity has arisen of examining two patients only who were suspected of having a cortical abnormality. They were both examples of the Cushing syndrome.

It was felt that the maximum information regarding the size, shape and position of the gland could be determined by combining aortography with air insufflation and this was done in each case. Air insufflation was carried out by the pre-sacral technique under local anaesthesia half an hour before aortography under general anaesthesia.

These patients are described below:-

Case (119) A.C. Female aged 58.

History.

This woman was admitted to a Medical Unit in January 1955. She had suffered severe headaches and lassitude for two years. During this time she had put on weight, almost two stones, and had become very breathless. She had also noticed that her complexion was more florid and that there had been growth of hair on the face. On examination she displayed the typical characteristics of Cushing's syndrome. She was a stout, highly-coloured, moon-faced woman. The neck and abdomen were fat and the skin showed pigmentation with striae on the flanks. She had marked hypertension - 240/130 mm./Hg.

with blurring of the optic discs. X-Ray examination showed enlargement of the heart and decalcification of the spine.

The various biochemical and hormonal tests were equivocal and she was referred for further investigation in the Urological Department.

Urological Investigation.

Excretion urography on 18.3.55 showed no abnormality other than the left kidney lying at a slightly lower level than the right. Whilst this reversal of the usual position is not uncommon in otherwise normal patients, the possibility of an enlarged left adrenal gland displacing the kidney downwards could not be discounted.

On 21.3.55 combined aortography and air insufflation was carried out.

This shows (Fig. 190) the left inferior adrenal artery arising from the aorta above the left renal artery. It is not particularly hypertrophied and its termination is not defined.

The nephrogram phase (Fig. 191) shows that the left adrenal gland appears to resemble more the "cocked-hat" outline of a normal right gland but there is little appreciable enlargement present.

A presumptive diagnosis was made of cortical hyperplasia rather than tumour although a dogmatic attitude was not adopted.

Operation.

The left adrenal gland was explored on 12.4.55. (W.B.S.) The gland was enlarged and thickened which presumably accounted for the X-Ray appearances. The condition, however, was obviously one of hyperplasia and not tumour. Sub-total adrenalectomy was carried out on this gland with a view to removal of the right gland at a later date.

This patient developed a hypertensive crisis two weeks after the operation and died of cerebral haemorrhage.

Post-mortem examination confirmed hyperplasia of the right adrenal cortex, the gland, however, being but little enlarged.

Case (120) C.S. Female aged 42.

History.

This nurse was admitted to a Medical Unit on 4.10.55. She stated that over the previous two years she had noted an increasing growth of hair on the face, increase in weight of one and a half stones and a change in her facial appearance.

On examination she displayed the typical plethoric moon-face and fat distribution of Cushing's syndrome. The blood pressure was 170/120 mm./Hg. X-Ray showed spinal osteoporosis.

The various biochemical and hormonal examinations were equivocal. She was referred for aortography on 2.11.55.

This was combined with air insufflation and shows (Fig. 192) a normal renal vascular supply on each side. There is no filling of any of the adrenal arteries, none of which can be identified and there is no evidence of vascularity within these glands. This film and subsequent nephrograms, however, suggested the presence of an enlarged tissue mass overlying the upper pole of the left kidney. These appearances proved puzzling and it was felt that if the latter were indeed an adrenal tumour there should have been more direct evidence of this in the arteriogram phase.

No definite diagnosis was reached on these films and it was decided to explore the left adrenal in the first instance.

Operation.

On 22.11.55 the left adrenal gland was exposed. (W.B.S.) No tumour was present but the gland was definitely enlarged in size and thickness. Sub-total adrenalectomy, removing nine-tenths of the gland, was carried out.

On 6.12.55, right total adrenalectomy was performed. (W.B.S.)

Histological examination of both these glands confirmed hyperplasia of the cortex.

The response to surgical treatment has been very satisfactory there being marked improvement in her appearance and weight. The blood pressure has remained normal, 120/80 mm./Hg.

SUMMARY AND CONCLUSIONS.

An appreciation of the contribution of angiography in lesions affecting the adrenal glands is not possible on two cases.

Both patients were examples of cortical hyperplasia and in neither of them was increased vascularity shown on the arteriogram.

In the first patient, the adrenogram showed no appreciable enlargement and in view of this and the absence of hypertrophied adrenal arteries a diagnosis of hyperplasia was made. Further experience is necessary before such findings can be taken to exclude tumour.

In the second patient, no increased vascularity was shown on the arteriogram phase but the adrenogram suggested enlargement of the left gland. This proved misleading as hyperplasia was confirmed at operation but there was no enlargement to the extent suggested on X-Ray examination.

The demonstration of tumours has been proved by others but in each case the size of the growth was considerable.

It is felt that any diagnostic method which may contribute to the problems of adrenal disease should not be ignored and that further experience is necessary before the practical value of the procedure can be assessed.

VESICAL NEOPLASM.

The value of aortography in demonstrating certain blood vessels within the pelvis is now recognised. In practice this consists of the visualisation of the common and external iliac arteries and the collateral circulation in cases of intrinsic obliterative vascular disease. The only other vascular supply which has been investigated by aortography is that of the uterus and placenta in the late stages of pregnancy. This has a practical application in the diagnosis of placenta praevia. (Hartnett, 1948)

The demonstration of the blood supply to the bladder has not previously been reported and it was thought of interest to investigate this, especially in cases of tumour affecting that organ. It was realised that even where visualisation was successful the practical application of this knowledge must be extremely limited. The demonstration of the vesical blood supply might be of value where cystectomy or partial cystectomy was contemplated. These operations, however, comprise only a few of the total operations carried out for bladder tumour. Arteriography cannot be of value for perurethral or transvesical diathermic operations.

As regards the type of tumour, the massive papillary neoplasm might be expected to be associated with an increased blood supply, unlike the relatively avascular squamous type.

In the light of present knowledge there is no relation between the degree of vascularity and the degree of malignancy. Further, the occurrence of blood-borne metastases depends, not on the blood supply, but on the grade of malignancy and extent of invasion. Whether the occurrence of metastases in tumours of comparable malignancy and invasion is influenced by the degree of blood supply is at present a matter of considerable conjecture.

Bearing these points in mind it was decided to use aortography in a few cases of bladder tumour. Several technical difficulties were encountered. Experience in low aortography for peripheral vascular disease showed that the internal iliac arteries did not fill as well as the external or common iliac vessels. The named branches of the former could seldom be positively identified.

In view of this, it was decided to modify the usual technique of low aortography in an attempt to obtain better visualisation of the intra-pelvic vessels.

This was done in the first two of the three cases described below but did not prove satisfactory.

Case (121) J.M. Male aged 49.

History.

This man had suffered intermittent haematuria for two years. Investigation showed that he had a large solid

type of papillary carcinoma occupying the left lateral wall and floor of the bladder.

Low aortography was performed on 5.11.54. In this case both femoral pulses were obliterated by sphygmomanometer cuffs on each thigh. It was hoped that such obstruction would permit greater filling of the internal iliac arteries and their branches.

The arteriogram (Fig. 193) shows that no material change was achieved by this method. The quality of the film is not as good as usual and it is felt that this may be due to excessive slowing of the circulation. No useful information resulted from the examination.

Case (122) J.M. Male aged 64.

History.

This man complained of haematuria of four months duration. Examination showed a bulky papillary carcinoma of the right postero-lateral wall of the bladder.

Low aortography was performed on 6.12.54.

In view of the results in the previous case it was decided to use manual compression of both femoral arteries and to release the pressure in the course of injection of the dye. This film (not illustrated) proved even less satisfactory as some movement occurred after the release of pressure with consequent blurring of the arterial outline. Again no useful

information was gained.

In the last patient the normal low aortographic technique was used without modification.

Case (123) W.M. Male aged 57.

History.

This man had suffered continuous painless haematuria for ten weeks previous to examination. He admitted to several transient attacks of bleeding over the preceding year.

Examination showed that almost two-thirds of the bladder appeared to be replaced by tumour. This was thought to arise from a broad base on the inferior aspect of the left lateral and posterior walls of the bladder.

Low aortography was performed on 4.4.55. This shows (Fig. 194) that the external iliac and femoral vessels are better filled than the internal iliac and its branches. There is, however, an undoubted increase in the size and number of the branches of the left internal iliac artery.

This affects particularly the inferior vesical and internal pudendal arteries. The former may be seen running medially and terminating in two fairly large divisions.

Operation.

Total cystectomy and bilateral uretero-colic anastomosis was performed on 11.4.55. (W.B.S.) At operation

the blood supply to the left side of the bladder was appreciably greater than that on the right side. This increase, however, affected not only the inferior vesical leash but also the superior vesical vessels although to a slightly lesser degree.

SUMMARY AND CONCLUSIONS.

Aortography yielded no information in Cases (121 and 122). The increased blood supply shown in Case (123) and confirmed at operation proved interesting but of little practical value. It is felt that at the present time aortography has nothing to offer in the management of vesical neoplasm.

HYPERTENSION.

The publication by Goldblatt (1937) of his experimental results in the field of hypertension stimulated fresh interest in this puzzling syndrome. At first it was thought that the solution to the problem of hypertension was at hand and physicians and urologists alike began to review their hypertensive patients hoping that a relatively simple surgical procedure - nephrectomy - might provide the answer. The problem of selecting the renal hypertensive patient from the general case of hypertension was soon found to be a difficult one.

Hypertension is a common condition but there is now agreement that hypertension due to or associated with a unilateral renal lesion occurs in less than 5% of the total cases. Further, the presence of a unilateral renal lesion is by no means necessarily associated with raised blood pressure. A personal review of 371 patients who underwent operation for a lesion affecting one kidney in the Urological Department, Glasgow Royal Infirmary, in the five year period, 1949-1953, showed that only 49 patients (13%) had hypertension.

The results of urological surgery in hypertension are by no means constant and whilst there are records of many successful operations there are just as many patients in whom surgery has not not alleviated the condition whatsoever.

The intense examination of the kidneys in the hope of finding some evidence of unilateral arterial involvement has more often than not been painfully disappointing. Almost every condition of the kidney, congenital and pathological, has been studied in expectation of evolving accurate criteria for the solution of the problem of the "renal hypertensive patient."

At the present time it may be said that urological surgery is used in one of the following three circumstances:-

(1) Where the treatment of the renal lesion is vital and any effect on the hypertension is of secondary importance - for example, renal tumour.

(2) Where the renal lesion of itself justifies surgical treatment and there is reasonable hope that the hypertension may be alleviated - for example, calculus disease and hydronephrosis.

(3) Where surgery is undertaken principally to relieve hypertension, the renal lesion not necessarily of itself requiring surgical treatment - for example, pyelonephritis and hypoplasia.

It is generally accepted that before nephrectomy in Group (3) there should be evidence that there is a considerable disturbance of function of one kidney, the other being reasonably normal. Operations on patients over the age of 50

are unlikely to give a good result. Similarly, those with severe vascular disturbance, cerebral or cardiac, are unlikely to respond.

In spite of the various renal function tests, urographic and biochemical studies, too often there is a feeling of uncertainty in assessing the desirability of removing one kidney. This uncertainty persists and along with it a feeling of the incompleteness of the investigation.

This had led on the one hand to those who advise nephrectomy in almost every hypertensive patient showing some abnormality of one kidney, on the grounds that there is little to lose.

On the other hand, the number of poor results following nephrectomy, even in selected cases where a comprehensive investigation has been carried out, has led to some feeling of defeatism. A certain doubt remains regarding the value of the various urographic and function tests.

Urea clearance, water concentration and dilution tests, reflect only total renal function. They afford no information regarding the separate function of each kidney and it has been shown (Fullerton, 1923) that oliguria from one kidney may be masked by diuresis from the other.

Excretion urography affords no information of the quality of the urine and is not entirely reliable as a test of renal function.

Such tests are inadequate and reliance placed on these alone has undoubtedly been responsible for a number of poor results following nephrectomy.

There is no doubt that chromocystoscopy and differential renal analysis are more accurate in assessing the relative functions of each kidney. There are, however, certain technical difficulties in the collection of specimens and the calculation and interpretation of results.

Separate kidney specimens obtained by ureteral catheterisation only measure the function of each kidney as a whole and may not disclose the effect of important hypertensive factors such as localised ischaemia.

All these tests of renal function must reflect, to some degree, the blood supply of the kidney but they do not afford direct information regarding the vascularity of the organ.

The exact mechanism by which hypertension occurs in unilateral renal disease is still not known with certainty.

For many years it was accepted that the "Goldblatt kidney" produced the vasopressor agent renin from the ischaemic renal tissue. More recently it has been suggested that hypertension results from a failure of the kidneys to inactivate a normal extra-renal pressor factor. In unilateral renal lesions this entails a secondary functional disturbance of the opposite kidney.

Experimental work by Grollman et al. (1949) and Kolff et al. (1954) on dogs and by Floyer (1955) on rats suggests that the process is independent of excretion. This important conclusion, if true, might account for those cases in which ischaemia of the kidney exists without any significant alteration in the renal function and excretion analysis.

Whatever the mechanism there appears little doubt that ischaemia plays an important part.

There are two ways in which ischaemia of renal tissue may occur.

First, by an obliterative vascular process resulting from infection, pyelonephritis or tuberculosis; by a mechanical obliteration from intra-renal dilatation of the collecting system such as hydronephrosis or by a combination of them.

Second, by intrinsic vascular occlusion.

Whilst simple vascular occlusion is not common it is generally accepted that it is at least one way in which the syndrome may be produced. Proof of this is offered by the work of Goldblatt and many others and also by the clinical results following nephrectomy in which the kidney at or after operation shows such vascular deficiency.

In such cases there is little doubt that secondary factors arising within the kidney play an important part in the production and continuation of the elevated blood pressure. These factors, however, originate as a result of and in

response to interference with the renal arterial circulation.

It seemed only reasonable to turn attention to the study of the renal circulation by arteriography in cases of hypertension.

It was felt that additional information might be gained in each of the two types of renal lesion.

In the intrinsic vascular type, angiography should demonstrate interference of the renal circulation by the size, shape and distribution of the vessels both within and outside the kidney. Also the nephrogram should visualise infarcted areas within the kidney substance.

In the other type where vascular obliteration is secondary to infection or compression, further information regarding direct evidence of the vascularity and function of the kidney should be available.

It was realised that there are many difficulties associated with renal hypertension which could not be explained by one examination such as angiography. Also, that in the absence of any published series, the interpretation would prove difficult.

In the present series twenty-six patients with severe hypertension have undergone aortography. In a number of these there was no question of a unilateral renal lesion being considered the major causal factor. They have, however,

been included at this point to permit some discussion of the use of aortography generally in hypertension.

It has been asserted on several occasions that aortography is more difficult in the presence of a raised blood pressure. In my experience this is not entirely true. In such cases when puncture is properly carried out the increased flow of blood is so great and forceful that no doubt remains regarding the position of the needle point. From this aspect, therefore, the procedure is easier.

The difficulty lies in overcoming the increased resistance to injection. This cannot be achieved by the technique of manual injection and it has been my experience and that of others who use this technique that the films are of a poorer quality than the normal. The reason for this is obvious in that the rate of delivery of the dye is, of necessity, slower.

No such difficulty is encountered to any degree where a mechanical injector, such as has been described, is used. Allowance is made for this increased resistance by using slightly greater force so that the usual quantity is injected at the usual rate of delivery. This simple solution is still insufficiently recognised.

In the twenty-six patients studied in this series, excellent results were obtained in all but one.

In this case the fault was due not to the rate of injection but to movement of the cassette by an inexperienced radiographer.

Thirteen patients had a systolic pressure in excess of 200 mm./Hg. of whom five showed a pressure of 250 mm./Hg. None of the remaining thirteen had a systolic pressure below 170 mm./Hg.

As regards the danger of aortography in hypertension it is questionable if the hazard is appreciably increased. I do not consider the intra-aortic injection of an organic iodide more dangerous than intravenous injection in patients with raised blood pressure.

The administration of a general anaesthetic undoubtedly carries an additional risk in hypertension but in this respect reliance must be placed on clinical judgement and efficient modern anaesthesia.

Before describing the angiographic findings of the patients examined, a brief reference is made to the experience of others in this field.

Smith, Rush and Evans (1951) describe the angiographic appearances in five cases of renal infarction. Four of these patients had hypertension. Three of the five cases showed multiple large infarcts and one a single massive infarct. The appearances described are as expected, namely, a sudden termination of the affected vessel and a comparatively

avascular area between it and the periphery.

No mention is made of the condition of the contra-lateral organ or whether operation was carried out and, if so, the effect on the hypertension.

It is interesting to note that one of these patients, with demonstrable infarction, had no hypertension.

This is comparable to the case described by Melick, Yarborough and Boler (1951). The patient, a man of 44 years, developed right renal pain after an attack of coronary thrombosis. Aortography showed a partial occlusion of the right renal artery. Four months later aortography was repeated and there appeared to be complete blockage of that vessel, no dye being seen beyond it. This patient developed no hypertension over an observed period of four months.

Nelson (1945) quotes one case which he regarded as the "Goldblatt" type. The patient, a woman of 44, had intermittent hypertension, the blood pressure ranging between normal and 300 mm./Hg. systolic.

Renal function tests were normal but urography showed the left kidney to be smaller than the right.

Aortography suggested a blockage of the main vessel with budding of small arteries from the stump.

Nephrectomy was performed, the kidney showing arterio-sclerosis. No further details are available, except that there was no improvement of the blood pressure although

symptomatically there was considerable benefit.

Doss (1942) described two cases of hypertension in which vascular deficiency was shown on one side.

The first, a man aged 33, had a blood pressure of 190/130 mm./Hg. Excretion and ascending urography and renal function tests were normal. The arteriogram showed a "cut-off" after the main branching of the left kidney. No further detail is given as operation was refused.

The second case, a boy aged 12, with a blood pressure of 140/110 mm./Hg. was found to have hypoplasia of the right kidney. Angiography showed no blood supply on that side. After nephrectomy, the blood pressure fell and was maintained at 120/80 mm./Hg.

Burns and Hendon (1954) describe the angiographic appearances found in a child of 9 months of age who had a blood pressure of 200/180 mm./Hg. The right kidney had a double blood supply with aneurysms on each artery. Parenchymal vascularity appeared to be poor although excretion urography apparently showed normal function of each kidney.

Right nephrectomy was performed, the lower two-thirds of the kidney being ischaemic and a thrombus was found in the lower vessel. Fifteen months later the blood pressure still recorded the immediate post-operative record of 90/70 mm./Hg.

An interesting case has been described by J. Cid dos Santos (1955) son of Reynaldo dos Santos.

This was a young man who developed severe hypertension following a fall from a horse.

Arteriography was considered to show a post-traumatic thrombosis of the left renal artery and also a post-traumatic stenosis of one of two right renal arteries. Left nephrectomy partially ameliorated this condition.

It is interesting to conjecture if resection of the part of the right kidney supplied by the stenosed vessel might not have resulted in cure.

Riches (1955) quotes one case of a man of 25, with a blood pressure of 190/100 mm./Hg. in which arteriography showed marked diminution of the blood supply to the right kidney with only a faint nephrogram.

A small contracted kidney showing old pyelonephritis was removed and the blood pressure subsequently remained at 140/90 mm./Hg.

The hypertensive patients investigated in this series fall into three groups.

(1) Those in whom bilateral renal disease was present.

(2) Those in whom hypertension was not associated with a renal lesion.

(3) Those in whom a unilateral renal lesion was present or was suspected.

Detailed discussion of the first two groups is not pertinent to a review of hypertension due to unilateral renal disease and these patients are described under the disease for which they were investigated. Comment regarding these is confined to the general arteriographic findings.

Bilateral Renal Disease.

There were eight patients who may be included under this heading. Five of them are described elsewhere under the renal condition for which investigation was undertaken. The angiographic appearances in these were as follows:-

Case (71) was one of hydronephrosis. On the arteriogram (Fig. 120) the right renal vessels show the changes associated with renal dilatation. The marked vascular changes on the left side suggest athero-sclerotic obstruction of the main vessel with secondary cortical and medullary ischaemia. The latter may also in part be due to pyelonephritic changes.

Cases (28,29) were examples of bilateral polycystic disease. The illustrations (Figs. 53,54) show the vascular changes associated with this condition which was responsible for the hypertension.

The next case (Fig. 8) was one of an obstructing

ureteric stone and has been described under Hazards with reference to injection into one branch. Bilateral calculus disease had been present and the vascular abnormality of the right kidney is considered to be secondary to operation and not to be a factor in the hypertension which was present before operation.

Case (117) was one of bilateral renal aneurysm. (Fig. 188)

In the remaining three patients described below, marked vascular changes were present in both kidneys in one of them and none at all in the others.

Case (124) A.C. Female aged 67.

History.

This woman was known to have suffered from hypertension for several years. She was subject to headaches and attacks of dysuria. Ten days before being sent for examination on 12.3.55, she had suffered from urinary frequency and haematuria.

On clinical examination she was found to have marked peripheral arterio-sclerosis and a blood pressure of 250/115 mm./Hg.

Urological Investigation.

Cystoscopy on 12.3.55 showed no neoplasm but a mild degree of cystitis. The urine was infected with B. Coli.

Excretion urography on 13.3.55 showed some fullness of the right renal pelvis whilst the major calyces of the left kidney were somewhat distracted.

Aortography was done on 18.3.55.

Arteriography presented (Fig. 195) an interesting picture, the blood supply on each side being very deficient. The right renal artery is narrowed with an apparent constriction at its origin. This narrowed lumen is continued into the major branches and the terminal branches are few and irregular. There is an abrupt end to one of the major branches. The left renal artery shows a cone-shaped narrowing from its origin succeeded by a short length of normal calibre but again the major and terminal branches are thin and deficient.

The appearance of these vessels suggests advanced arterio-sclerosis with atheromatous obstruction.

The nephrogram showed each kidney to be reduced in size and of poor density.

The right kidney was almost half the normal size and had a patchy appearance as a result of relatively translucent areas, mainly in the medullary region. These areas were widespread, due to the considerable vascular deficiency and did not resemble the wedge-shaped areas of infarction resulting from obstruction in one major branch.

Renal surgery was not indicated in view of the bilateral nature of the lesions. The degree of vascular

damage and the age of the patient precluded sympathectomy.

Aortography was instructive in that the nephrogram indicated more clearly than the urogram, the size and shape of the kidneys. The arteriogram showed clearly the exact state of the renal arterial supply.

Case (125) J.F. Female aged 59.

History.

This woman was sent for examination on 22.4.55. She complained of intermittent attacks of pain in the left loin and also suffered from occipital headaches and felt tired and listless.

Urological Investigation.

Clinical examination revealed no abnormality of the urinary tract. The blood pressure was 195/155 mm./Hg.

Excretion urography suggested some slight dilatation of the calyces of the right kidney.

Ascending urography was performed on 27.4.55 but neither kidney was satisfactorily outlined.

Arrangements were made to admit her to hospital for further investigation but she was unable to come in to hospital until 11.10.55.

Urography, both excretory and ascending, was repeated and suggested slight clubbing of the calyces of each kidney. In order to exclude a definite ischaemic lesion, aortography

was performed on 17.10.55.

The arteriogram (Fig. 196) shows a good normal blood supply to each kidney. There is no evidence of arterio-sclerosis of the main branches and the nephrogram showed good parenchymal density with no evidence of any infarcted areas.

In view of these findings no operation was advised.

Case (126) M.O. Female aged 41.

History.

This woman was sent for examination on 17.11.53. Five weeks previously she had given birth to a full-time child but during the pregnancy had suffered a degree of toxaemia associated with a raised blood pressure. The hypertension continued and she was subject to headaches and "dizzy turns".

Urological Investigation.

On examination she was found to have a blood pressure of 170/100 mm./Hg. but no other clinical abnormality was found.

Excretion urography showed poor concentration of the dye on each side. This examination was repeated a month later and showed reasonably good concentration and no gross abnormality.

Ascending pyelography showed slight clubbing of the minor calyces suggestive of early bilateral pyelonephritis.

Aortography on 14.12.53 showed no significant vascular abnormality, the arterial pattern and nephrograms being those

of normal kidneys.

It was considered that the minimal changes seen on the retrograde pyelograms may not have been due entirely to infection but also to slight overdistension from excessive injection.

Even accepting the presence of bilateral pyelonephritis the pathological process had not reached the stage of affecting the blood supply. As the angiograms were quite normal they have not been included in the illustrations.

The second group, consisting of those patients with no apparent renal abnormality, includes many with aortic and peripheral vascular disease. They are fully described under these conditions and are not included here in an assessment of renal vasculature.

The other condition which may be included in this group, is that of Cushing's syndrome. This is described under Adrenal lesions but the arteriographic appearances showed little change from normal apart from a slight decrease in the total renal vascularity. (Cases 119,120)(Figs. 190,191, and 192)

The third and most important group consists of those in whom a unilateral renal lesion was present or suspected.

Altogether there were sixteen such patients. Five of

these may be regarded as belonging to the category in which investigation was undertaken with a view to operation for the renal condition in the hope that there might be improvement in the blood pressure.

They are described under the specific renal conditions and the following brief comments regarding the angiographic findings are included below.

Case (79) was one of calculus hydronephrosis. The arteriogram (Fig. 133) shows a reduction in the total renal vascularity of the affected side to less than half the normal. This was confirmed at operation. Following nephrectomy the blood pressure fell from 170/135 to 140/100 mm./Hg. This has been maintained for three months.

Case (78) was one of calculus hydronephrosis. The arteriogram (Fig. 132) shows considerable reduction in vascularity secondary to the dilatation. Whilst nephrectomy produced considerable symptomatic improvement there was no appreciable reduction in the pre-operative blood pressure of 255/110 mm./Hg.

Case (83) was one of renal calculus in which nephrolithotomy was carried out. The angiogram (Fig. 138) shows little reduction in the vascularity. Following

operation there was no appreciable fall in the blood pressure from the pre-operative level of 170/110 mm./Hg.

Case (100) was one of renal tuberculosis. The blood supply is shown (Fig. 168) to be deficient to the affected left kidney, that of the right side being fairly normal. No operation, however, has been carried out as this patient is receiving chemotherapy.

The last of these patients, not discussed under any other specific condition, is described below.

Case (127) M.L. Female aged 50.

History.

This woman was admitted to another hospital complaining of severe constant headaches of several months duration. She was found to have a severe hypertension of 230/140 mm./Hg. She had also complained of occasional pain in the right loin and some urinary frequency.

Amongst other investigations, an excretion urogram suggested a possible unilateral lesion affecting the right kidney.

She was referred for further investigation.

Urological Investigation.

Repeat excretion urography on 22.3.55 shows (Fig.197)

that concentration of the dye is moderately good on each side, the left kidney being anatomically normal in appearance.

The right kidney shows moderate dilatation of the renal pelvis with early clubbing of the minor calyces. The uretero-pelvic junction is rather narrow and below this the ureter is dilated and markedly kinked, the duplication extending a distance of one and a half vertebral bodies.

Aortography was performed on 25.3.55 to ascertain the renal vascularity and the possible presence of an accessory vessel in association with the ureteric "kink".

The arteriogram shows (Fig. 198) an irregular athero-sclerotic aorta with asymmetrical bifurcation, the right common iliac vessel deviating almost at right angles.

The renal arteries at their origin are within normal limits of size but the major divisions and terminal branches are thin and deficient.

No accessory vessel is present.

It was considered that operative treatment on the right kidney with a view to improving the blood pressure was not indicated per se.

It was thought possible to relieve the obstructive element by uretero-pyeloplasty and so improve the function of the right kidney. After deliberation this was attempted.

Operation.

At operation on 29.3.55 (W.B.S.) the upper ureter

and the area of duplication were found to be embedded in a chronic inflammatory mass. The pelvis was very unhealthy-looking and friable and during mobilisation was avulsed from the ureter. Under these circumstances nephrectomy was performed.

The operation was performed essentially to attempt to improve renal function and not as a direct attack on the hypertension.

Following removal of the kidney, the blood pressure fell to 120/70 mm./Hg. As was expected, there was a gradual rise over the next month to 170/95 mm./Hg. There was considerable symptomatic improvement, the patient sleeping well and free from headaches.

It was anticipated that the blood pressure would not remain at that reasonable level and reports six months later show that it has risen to 230/105 mm./Hg., although the patient is apparently free from any serious subjective symptoms.

In the remaining eleven cases in this group investigation was undertaken with a view to renal surgery as a relief for hypertension.

The suspected conditions were as follows:- Minor hydronephrosis (3), renal pain of unknown origin (1) aneurysm of renal artery (1), hypoplasia (2), congenital duplication of the pelvis (1) and non-functioning kidney (2)

these are described below.

Case (128) C.F. Female aged 56.

History.

This woman was admitted to another hospital on 31.1.55. She complained of severe headaches, blurred vision and general lassitude. She also had urinary frequency at times and for several years had felt an ache in the right loin.

Examination showed marked hypertension, 200/120mm./Hg. In the course of investigation, excretion urography was performed and reported as showing "a moderate degree of right hydronephrosis."

She was referred for further urological examination.

Urological Investigation.

Cystoscopic examination on 22.4.44 showed no significant abnormality. Bilateral ascending pyelography showed early moderate dilatation of both renal pelves with slight dilatation of the right calyces and ureter.

Separate renal function tests showed the kidneys to have approximately equal clearance - 50% normal. The blood urea was 34 mgm./%.

Aortography was carried out on 25.4.55 to determine the renal vascular supply.

The arteriogram (Fig. 199) shows reasonably good renal vascularity on each side.

The main left renal artery shows a definite constriction a short distance from the aorta. Beyond this, there is further irregularity of the vessel denoting advanced arterio-sclerotic changes in the walls. The vascular flow, however, seems adequate and no discrete ischaemic area may be made out.

The angiographic and urographic findings suggest that urological surgery was not indicated in this patient, the condition not being truly a unilateral one.

Case (129) J.S. Female aged 60.

History.

This woman was admitted to another hospital complaining of headaches, dizzy attacks and occasional "black-outs". These symptoms had been present intermittently for eight years. She was found to have a marked hypertension of 240/105 mm./Hg.

In the course of investigation an excretion urogram was performed which showed early extra-renal dilatation of the right renal pelvis.

She was referred for further examination.

Urological Investigation.

Aortography was carried out on 13.5.55.

The arteriogram (Fig. 200) shows a satisfactory renal vascular supply to each side. There is also a noticeable

narrowing of the left renal artery near its origin from the aorta. The mottling seen near the upper pole is not pathological and was noted on the preliminary film - it is probably due to bowel content.

It is interesting to note a large right supra-renal vessel arising from the renal artery. The adrenal gland was clearly shown on the nephrogram phase.

Apart from the age of the patient, the duration of symptoms and the minor dilatation of the right kidney, the arteriographic appearances did not indicate the need for urological surgery. These appearances suggested arterio-sclerosis secondary to and not primary to the hypertension.

Case (130) S.G. Female aged 56.

History.

This woman had been admitted to a Medical Unit in October, 1953, suffering from hypertension. The blood pressure was 250/150 mm./Hg. She was found to have a massive calcified non-functioning left kidney. In view of pain and persistent urinary infection this kidney was removed on 17.11.53. (W.B.S.)

Nephrectomy had no effect on the hypertension.

She was examined at intervals following the operation and subsequent urograms suggested an increasing dilatation of the remaining kidney.

Urological Investigation.

Excretion urography on 4.2.55 showed some dilatation of the renal pelvis with a degree of "cut-off" at the uretero-pelvic junction.

It was decided to carry out aortography to ascertain the state of the arterial tree and the presence or absence of an accessory vessel. This was done on 2.5.55.

The arteriogram (Fig. 201) clearly shows athero-sclerotic changes in the aorta. There is a double blood supply to the remaining right kidney, the faint parenchymal outline of which may be seen even in this phase.

The main vessel supplying the upper two-thirds of the kidney shows a well-marked atheromatous constriction at its origin from the aorta. The vessel and its main branches are rigid and tortuous - indications of sclerotic change. The lower vessel is similar and the peripheral supply of each is poor.

It was not considered that this accessory artery was responsible for a uretero-pelvic obstruction as it lies much lower than that junction.

Apart from the patient's age and the obvious changes affecting the main vessels there was no evidence of a clear infarcted area to justify operation on this kidney.

Case (131) E.M. Female aged 44.

History.

This woman was referred from another hospital for urological examination on 2.5.55 with the following history. She had been known to suffer from hypertension for at least six years. Splanchnicectomy had been performed in 1949 without any material benefit. Two weeks previous to being referred for examination she had suffered pain in the left renal area and excretion urography had shown no evidence of dye concentration on that side.

Urological Investigation.

On clinical examination she was a rather stout and plethoric-looking woman. No pain or tenderness was present in either loin and the kidneys were not palpable.

The blood pressure was 200/120 mm./Hg.

Urine analysis was normal.

Excretion urography was repeated which showed rather faint concentration of the dye and some fullness of the upper calyces of each kidney suggestive of chronic pyelonephritic change. These appearances did not suggest that a unilateral lesion was present but aortography was performed on 19.5.55 to determine the vascular appearances.

This shows (Fig. 202) some athero-sclerotic change in the aorta, which has a high bifurcation.

The renal vascularity on the left side is somewhat

lacking in the small cortical branches and there is marked kinking of the main vessel. Otherwise the vascularity of each kidney is adequate and there is no evidence of any infarction. The silver clips inserted at the splanchnicectomy are clearly seen.

The nephrogram showed satisfactory density of the dye on each side.

These findings did not indicate that renal surgery should be employed.

The next patient was also referred under similar circumstances.

Case (132) J.W. Female aged 61.

History.

This woman had a dizzy attack and became unconscious for a short period in February, 1955. She was admitted to another hospital for observation. Examination showed that she had a high blood pressure of 210/110 mm./Hg.

X-Ray of the urinary tract showed a calcified ring shadow in the right renal area. The possibility of renal aneurysm was considered and she was referred for further examination.

Urological Investigation.

Excretion urography on 11.5.55 showed an apparent

calcified ring shadow opposite the transverse processes of the first and second lumbar vertebrae.

There was moderately good function of the right kidney but there was a constriction of the neck of the upper major calyx with a degree of hydrocalicosis. The function of the left kidney was poor and little detail could be made out.

Aortography was performed on 13.5.55 but was unsatisfactory, the cassette being moved too quickly. Repeat pictures were made five days later, on 18.5.55, to determine the nature of the calcified shadow and the state of the arteries.

The arteriogram (Fig. 203) shows the irregular deviated athero-sclerotic aorta. The renal arteries are fairly normal but the terminal distribution is poor, the vascularity being more deficient on the left side. The shadow suspected of being an aneurysm is not connected with a major renal vessel and on the subsequent nephrogram and lateral films was clearly shown to be unconnected with the kidney or its blood vessels.

No operation was indicated in this case.

In spite of the hypertension, no ill effect attended two aortic punctures within five days of each other.

It is interesting to find that the patient (Case 117) with renal aneurysm had only moderate hypertension.

The following two patients are examples of unilateral renal hypoplasia.

Case (133) K.F. Female aged 22.

History.

This woman was seen on 10.6.52 complaining of right-sided pain. This had been present for six months but following a miscarriage two months previously, excretion urography had been carried out in the Royal Maternity Hospital which showed no function of the left kidney. During her pregnancy she was found to have a high blood pressure - 180/115 mm./Hg. and she was referred for further examination of the urinary tract.

Urological Investigation.

Excretion urography on 10.6.52 confirmed the absence of function of the left kidney, that of the right being normal.

Left ascending pyelography a week later showed a hypoplastic kidney. She was admitted to hospital later and on 4.8.52, aortography was carried out.

This early film, not suitable for reproduction, showed a very poor blood supply to the left side. The main renal artery was greatly reduced in size and appeared to peter out in two small terminal branches. No appreciable nephrogram effect was seen.

Operation.

Left nephrectomy was performed on 6.8.52. (W.B.S.) The kidney was greatly reduced in size, measuring 5 x 3 cm. The pedicle was extremely small and narrow and no pulsation could be felt.

Histology showed the changes of chronic pyelonephritis.

Fourteen days after operation the blood pressure recorded 155/95 mm./Hg. This patient has had two subsequent pregnancies during which there was a considerable increase in her blood pressure. At the present time, three years after operation, the blood pressure is 180/100 mm./Hg.

Case (134) G.R. Female aged 23.

History

This young woman was found to have hypertension in the course of a routine medical examination. She had no symptoms referable to the condition and no albuminuria.

The blood pressure was 210/125 mm./Hg.

Excretion urography showed poor function of the left kidney and she was referred for further examination of the urinary tract on 20.1.53.

Urological Investigation.

Excretion urography on this occasion showed good concentration of the dye from a small left kidney, the right

being normal. She was admitted to hospital and ascending pyelography on 20.2.53 confirmed hypoplasia of the left kidney.

Aortography was carried out on 22.2.53 which showed normal vascularity of the right kidney. The outline of a small left kidney was seen but whilst there was reduction in the size of the renal artery and its branches no marked vascular deficiency was seen. The appearance was that of a diminutive normal pattern.

The nephrogram showed a reasonably good dense parenchymal shadow of a small kidney.

These films are not illustrated as they are early ones in which hand pressure was used and do not reproduce satisfactorily.

Operation.

Left nephrectomy was performed on 24.2.53. (W.B.S.) A small kidney measuring 5 x 2 cm. and weighing 14 gm. was removed.

The renal substance appeared to be firm and of normal consistency. Marked foetal lobulation was present.

Histological examination of the kidney showed no abnormality apart from a tiny linear scar, the arterioles of which showed endarteritis. It is presumed the scar resulted from a previous infection.

The immediate post-operative effect was very satisfactory, the blood pressure being reduced to 145/95 mm./Hg.

Six months later the pressure had risen to 160/100. No further record of this patient is available.

The next patient was one who had a severe hypertension associated with a congenital anomaly of one kidney.

Case (135) J.H. Male aged 18.

History.

This young man was found to have severe hypertension whilst serving in the Army. He was admitted to a Military Hospital where the blood pressure was found to vary between 200/150 and 230/150 mm./Hg.

Urological Investigation.

Investigation of the urinary tract showed duplication of the right renal pelvis and upper ureter, the left being normal. Function as assessed by concentration of the dye was not very good but was apparently equal on both sides. As is usual the upper segment of the right kidney was smaller than the lower. The appearances, however, did not suggest a pyelonephritic lesion.

He was admitted to the Royal Infirmary and referred for further investigation.

Aortography on 10.12.54 was performed especially to determine the blood supply to the two segments of the right kidney. It was thought possible that a deficient vascularity

might exist in spite of the apparent equality of dye concentration.

The arteriogram (Fig. 204) shows a good main blood supply of normal pattern to each kidney. No area of relative avascularity either of the arteriogram or nephrogram phase could be seen anywhere in the kidneys. This normal renal vascularity suggested that the common congenital anomaly of pelvic duplication was of no clinical significance and that the condition was not due to a unilateral renal lesion. Urological surgery was therefore not advised.

Therapeutic tests and air insufflation did not suggest a specific lesion of the adrenal glands.

No operative treatment was carried out.

Medical treatment with the hypotensive drugs, Ansolysin and Serposil has succeeded in maintaining a blood pressure of 175/120 mm./Hg.

The next patient was thought to be an example of unilateral nephrosclerosis associated with hypertension.

Case (136) M.G. Female aged 27.

History.

This young woman had a long and involved medical history much of which she concealed. She had suffered headaches and dizzy attacks for six years. Five years

previously she underwent a Caesarean section for profound toxaemia of pregnancy with eclamptic seizures. She continued to have a high blood pressure, 220/110 mm./Hg. She was investigated and treated in medical units in at least four different hospitals. No gross urological abnormality had been found.

Following a complaint of persistent, fairly severe pain in the left loin she was referred direct from her own doctor for further investigation of the upper urinary tract.

Urological Investigation.

Excretion urography on 2.4.55 showed no abnormality of the right kidney but no function on the left side. This was repeated with identical findings.

Aortography was carried out on 8.4.55 to determine any possible vascular abnormality.

The arteriogram (Fig. 205) is not entirely satisfactory as some blurring has occurred due to slight movement of the patient from anaesthetic difficulties. There is, however, a definite difference in the vascular pattern. On the left side a branch is given off from the main artery near its origin to supply the upper part of the kidney. The main vessel then divides into three smaller vessels in the region of the hilum.

No peripheral vascularity is seen and no appreciable nephrogram effect was obtained on that side.

It was decided to explore the left kidney.

Operation.

At operation (W.B.S.) on 11.4.55, the kidney was seen to be small - about two-thirds the normal size. The vessels running into the hilum were narrowed and only about half the size of the normal.

There was no evidence of aortic athero-sclerosis.

Nephrectomy was carried out in the hope that the hypertension was associated with these unilateral vascular changes. For two weeks the blood pressure remained at a reasonable level - 180/95 mm./Hg. but thereafter there was a steady climb to the pre-operative figure of 200/120 mm./Hg.

The next patient was one in whom a labile hypertension was associated with a non-functioning hypoplastic kidney. The immediate result of operation has been very satisfactory.

Case (137) M.B. Female aged 26.

History.

This young woman was sent for urological examination on 12.10.55. Two weeks previously she had had a severe attack of urinary frequency with dysuria and pyuria. At this time she had tenderness in both loins and had noticed slight transient haematuria at the beginning of the illness. She

also stated that she had suffered occasional aching pains in the right loin since childhood and more recently had suffered from headaches and a feeling of general lassitude.

Urological Investigation.

On clinical examination she did not look well although her general physique was good. There was slight tenderness in the left loin. The blood pressure was 135/100 mm./Hg.

Excretion urography showed good concentration of the left kidney but no dye was seen on the right side. A week later, cystoscopy was performed and showed no abnormality. Two specimens of urine, however, showed only a few epithelial cells but no growth of organisms on culture.

Right ascending pyelography shows (Fig. 206) dilatation of the pelvis and flattening of the calyces. In addition to the degree of pelvic hydronephrosis it was considered that the calyceal appearances might be due to a degree of hypoplasia. It was not possible to be dogmatic about this as no indication of the parenchymal outline was afforded on the urographic films.

In view of the unilateral lesion and the finding of hypertension she was admitted to hospital for further investigation. On admission her general condition was unchanged although her urinary symptoms had almost subsided. After rest in bed for 24 hours the blood pressure became

reduced to 130/85 mm./Hg. and remained at that level.

Aortography was performed on 18.11.55. The arteriogram shows (Fig. 207) a hypertrophied main left renal artery with excellent parenchymal distribution to an enlarged kidney. On the right side the total vascularity consists of a very thin main vessel arising at the level of the middle of the 1st lumbar body and terminating in two tiny main divisions. There is no appreciable parenchymal vascularity and it was considered that the blood supply was sufficient only for viability of the remaining renal tissue and not for effective renal function.

No nephrogram effect was obvious on the right side.

These clinical and radiological findings appeared to justify removal of the right kidney.

Operation.

The right kidney was explored on 22.11.55. (W.B.S.) The kidney was extremely small consisting of a crescent of tissue not much larger than 1 cm. in size, situated above a dilated pelvis. This dilated hypoplastic kidney was removed, the pedicle being extremely thin.

Histological examination showed signs of chronic pyelonephritis with interstitial cellular exudate and fibrosis and hyalinization of groups of glomeruli.

The immediate result of the operation has been very satisfactory. There has been no recurrence of headaches and

her general health is good. The blood pressure two months after operation remains at 120/70 mm./Hg.

The last patient with hypertension associated with a unilateral renal lesion proved interesting in that a marked vascular abnormality was shown on aortography and nephrectomy produced a dramatic sustained improvement.

Case (138) H.W. Male aged 53.

History.

This man was admitted to a Medical Unit of another hospital on 24.3.55. He complained of headaches, tiredness and poor vision which had been present for some four months. On examination, distinct arterio-sclerotic changes were present, the superficial arteries being easily palpable. The blood pressure was elevated and ranged between 170/110 and 220/120 mm./Hg. The heart was not enlarged clinically or radiologically. The electrocardiogram showed some myocardial changes but no left ventricular preponderance. The urine contained albumen - 1-3 parts Esbach. The deposit showed some red cells and hyaline tube and granular casts. The blood urea was 26 mgm./% but the haemoglobin and stained films were normal.

Opthalmic examination showed gross fundal changes consisting of papilloedema,"nipping" of the arterial-venous

crossings, exudate and some haemorrhage.

It was considered that there might be raised intracranial pressure and ventriculography was carried out which was essentially normal.

Thereafter excretion urography was performed which whilst showing satisfactory function and anatomical outline of the left kidney failed to show any dye on the right side. He was referred for further examination of the urinary tract on 12.5.55.

Urological Investigation.

Clinical examination confirmed the previous findings the blood pressure being sustained at 180/110 mm./Hg.

Cystoscopy showed no bladder abnormality and right ascending pyelography suggested that the right pelvis and calyces were normal apart from minimal clubbing of the calyces.

Excretion urography was repeated on 16.8.55. This showed the left kidney to be normal but on the right side no excretion of dye was visible.

Aortography was carried out on 18.5.55.

The arteriogram (Fig. 208) shows the left renal vascularity to be fairly normal.

On the right side there is a complete block and abrupt ending in the right renal artery 0.5 cm. from its origin.

No nephrogram effect was obtained on that side.

This striking appearance suggested that a Goldblatt type of kidney was present on the right side. Nephrectomy was recommended for the relief of the hypertension.

Operation.

The right kidney was exposed on 23.5.55. (A.J.) Careful examination of the pedicle revealed that pulsation was present in one branch although the main pedicle was reduced in size. Ligation was carried out as close to the aorta as possible and the kidney removed.

Examination of the specimen showed that it weighed 85 gm. No obvious abnormality was seen in the kidney substance although the arteries were narrowed and obviously arterio-sclerotic. The main renal artery was rigid and reduced in size but no complete occlusion was present.

Histological examination showed relatively bloodless glomeruli and thickening of the intra-renal arterioles. The tubules showed focal dilatation and contained hyaline casts.

The main renal artery showed medial hypertrophy and patchy intimal thickening due to atheroma.

The progress of this patient was very satisfactory. At the end of the operation the blood pressure registered 160/100 mm./Hg. The following day it was 100/60 and there was a gradual rise to 150/95 mm./Hg. over the next three days. This decreased over a period of a few days until at the end

of a week it stabilised at 120/75 mm./Hg. and has remained at that level for six months.

There are now no obvious eye changes and the patient's general health and mental outlook are considerably improved.

Several points of interest arise in this case.

No obvious function was shown on excretion urography although the retrograde pyelogram suggested only minimal changes. Occlusion of the main renal vessel was shown on arteriography.

At operation some pulsation was felt beyond the point of dye obstruction and total occlusion was not found on careful dissection and histological examination of the specimen. It is felt that whilst the arteriographic appearances were not absolutely accurate they contributed valuable pre-operative information in this patient.

The appearance of complete blockage shown on one X-Ray film has been noted in stenosed or obstructed vessels in peripheral vascular disease. In these cases, as will be described, a second injection is frequently made to obtain arteriograms at a slightly different time and in these subsequent films a trickle of dye through the stenosed area may be seen. It is for this reason that I feel that fast photography or cine-radiography is essential for a fuller

interpretation in cases of obstruction and for a more complete understanding of the renal circulation in hypertension.

SUMMARY AND CONCLUSIONS.

The production of good quality films in hypertension is feasible provided an efficient technique is used.

The pathological changes affecting the larger arteries in hypertension can be visualised by angiography. Athero-sclerosis of the aorta and renal arteries, arterio-sclerosis of the smaller branches and stenosis or blockage of any of these may be shown.

The actual and potential function of each kidney which is dependent on the main blood flow and the parenchymal supply can be assessed with greater accuracy by angiography than by any other radiological method.

Whilst no example of localised ischaemia has been encountered in this short series it has been proved by others that it is possible to demonstrate this. In the light of present knowledge concerning a renal ischaemic factor in hypertension this appears to afford a valuable contribution.

In this study ten patients with a unilateral renal lesion of one type or another were submitted to operation.

The affected kidney was removed in nine of them.

In the remaining patient (Case 83) nephrolithotomy only was performed and there was no effect on the blood pressure. This patient showed no renal vascular or aortic abnormality.

Of the nine patients who underwent nephrectomy, five derived no reduction in the blood pressure. Three of these (Cases 78,127,130) showed athero-sclerotic changes in the aorta, with or without athero-sclerosis or arterio-sclerosis affecting the vessels of the other kidney.

Four patients showed reduction in the level of the blood pressure following nephrectomy. This did not return to normal in two of them (Cases 79,134) but was accompanied by considerable symptomatic improvement. In the remaining two patients (Cases 137,138) the blood pressure returned to normal and has remained at that level. In none of these four patients was any vascular change apparent in the aorta or contra-lateral kidney.

The significance of vascular changes, other than in the affected kidney, is not easy to assess absolutely.

The two patients (Cases 133,136) with poor operation results and no such changes were between the ages of 20-30 whilst the three showing aortic or contra-lateral renal vascular abnormality were over the age of 50 years.

Age alone, however, does not account for the changes

as the patient (Case 138) who showed the most dramatic result was over 50 years of age.

This suggests that such changes are secondary to established hypertension of some duration and that these changes, not otherwise demonstrated except by arteriography, constitute a further criterion against nephrectomy.

The demonstration of intrinsic vascular disease affecting one kidney only appears to be a further valuable contribution.

It is felt that renal angiography should form an essential part of the investigation of hypertension where nephrectomy is contemplated.

INTRINSIC VASCULAR DISEASE.

The surgery of vascular disease is not new. Whereas formerly it consisted of ligation, either for aneurysm or arterial injury, it is now possible to perform direct disobliterative or reconstructive operations on blood vessels.

The feasibility of replacing diseased portions of the peripheral arterial tree by arterial grafts was proved some fifty years ago. Until recently, however, such operations were only possible if and when a suitable graft was available. The discovery of several plastic substances and the technique of freeze-drying arteries so that they may be stored in a "tissue bank" now make reconstructive operations possible at any time. These facilities along with advances in surgical technique, antibiotic and anti-coagulant therapy have enlarged the whole field of vascular surgery and contributed much to the success of such operations.

It is not surprising that with the expanding scope of vascular surgery there should be a concomitant desire for increased accuracy in diagnosis.

In most cases of vascular disease, especially that of the peripheral vessels, a fair assessment of the state of the arteries and the level and extent of obstruction - if present - may be made on clinical examination. Thus, the history and symptoms, observation of the pulses, the nutrition

and temperature of the parts usually serve to indicate the approximate level of obstruction. Ancillary measures, such as oscillometry, may give further help.

Where direct surgery is contemplated it is essential to have the most accurate information regarding the level and extent of obstruction and the state of the remaining arterial tree. This is best furnished by arteriography.

Reference has been made in the historical section to the work of Brooks (1924) who introduced arteriography of the lower limb by puncture of the femoral artery. Such techniques have been used extensively since then and the value of peripheral arteriography recognised.

Learmonth (1944) in summarising the purposes of outlining the peripheral arterial tree, states that they include the demonstration of :-

(1) Its anatomical arrangement, whether normal or abnormal.

(2) The presence of local irregularities of calibre in arteriosclerosis or Buerger's disease.

(3) Thrombotic blockage of main trunks in obliterative vascular disease.

(4) The extent of collateral circulation.

(5) The site and extent of arterial aneurysm.

(6) The site of arterio-venous fistulae.

The good results obtained by surgery in disease of the peripheral vessels stimulated the application of similar methods for the treatment of disease affecting deep-seated arteries within the abdomen and pelvis.

The practical value of peripheral arteriography called for a similar standard of visualisation of the abdominal and pelvic vessels. The techniques used for peripheral arteriography, however, are not suitable for this. The demonstration of these vessels by femoral puncture either by the percutaneous method or by puncture under direct vision after exposure of the artery can only be achieved in two ways.

First, by forcible retrograde injection. In practice this is not satisfactory. It is seldom possible to outline the lower aorta and the iliac vessels of each side. It is important that these be defined even in cases of suspected unilateral disease. Where obstruction of the common or external iliac arteries exists, dye cannot be made to ascend to any extent. Excessive pressure in an attempt to negotiate such obstructions is dangerous where intrinsic disease affects the vessel.

The second method is by retrograde catheterisation from the femoral artery. Apart from the obvious danger of trauma during manipulation of the catheter, the presence of stenosis or irregularity of the calibre or course of the vessel will render the procedure impossible.

In my opinion there is no place for such techniques in intrinsic vascular disease.

Translumbar aortography offers the surest and safest means of visualising the abdominal and pelvic arteries.

Although in his early communications dos Santos had indicated its potential value in this field it has not been used to any extent until quite recently and has lagged behind renal angiography.

Thus, Leriche (1940) in describing the features of thrombosis at the aortic bifurcation made no reference to aortography but later (1948) referred to the work of dos Santos.

Price and Wagner (1947) described two cases of this syndrome confirmed by aortography and demonstrated the collateral circulation within the abdomen, pelvis and lower limbs.

The technique described for renal angiography is suitable for lesions affecting the upper and middle portions of the aorta. In the case of aneurysm it is important to avoid damage to the wall of the sac and to effect aortic puncture above the level of communication. No difficulty in this respect was encountered in the examination of the three patients with abdominal aneurysm. It is felt that an adequate assessment for the safe level of puncture may be made beforehand by clinical examination.

Where it is desired to illustrate the lower part of the aorta and its bifurcation and the iliac arteries, the same technique may be used. In my experience, however, it is preferable in such cases to perform low aortography. This is also applicable for the demonstration of the femoral arteries, especially their upper parts.

Low Aortography.

The same equipment is used as in the translumbar method. It differs in technique only in the level of puncture.

Skin puncture is made on the left side 8 cm. from the midline at the level of the 3rd lumbar body. The needle is advanced almost transversely so that aortic puncture is made at that level.

The advantages of low puncture are that there is little loss of dye into the major abdominal branches and a minimal diffusion so that a good concentration is obtained in the desired area. This is further enhanced by using the method of rapid injection.

Where arterial disease has caused irregularity or deviation of the lower aorta, puncture may be difficult at this level. Under these circumstances it is usually possible to enter the aorta at a higher level and obtain arteriograms which, although not so clear, are adequate for diagnosis.

The greatest difficulty at present in obtaining good pictures is in timing the correct X-Ray exposures. Arterial irregularities and stenosis alter the rate of blood flow and allowance must be made for this unless equipment for rapid serial exposures is available. Further, a single film may show an apparent total block of a vessel whereas later films may demonstrate that there is some blood flow through it. Also, time must be given to permit visualisation of the flow through the collateral circulation.

Most of these difficulties may be overcome by exposure at different intervals and using a second injection. The times will vary according to the level desired and the suspected type of lesion. In the cases of iliac and femoral disease described below, exposures were made at times varying between 1.5 - 3.0 secs. after completion of the injection, experience showing that this range is adequate for these lesions.

In this study twenty patients with real or suspected arterial disease have been examined by aortography. They have been divided into three groups according to the arteries involved.

AORTA.

Three conditions affecting the abdominal aorta - coarctation, aneurysm and stenosis - have been investigated.

(1) Coarctation.

Coarctation of the upper part of the abdominal aorta is a rare condition. The following patient was investigated by aortography, having been diagnosed as such elsewhere.

Case (139) N.G. Female aged 34.

History.

This woman was admitted to a Surgical Unit on 26.1.54 for treatment of coarctation of the aorta. This had been diagnosed at laparotomy in another hospital some weeks previously. The narrowing was reputed to be just below the origin of the superior mesenteric artery.

Investigation.

On clinical examination she appeared to be a healthy woman. No evidence of any aortic obstructive lesion of any degree was found on clinical grounds or following oscillometry of the lower limbs. In order to demonstrate the condition of the aorta she was referred for translumbar aortography on 5.2.54.

This shows (Fig. 1) the aorta to be absolutely

normal throughout its whole abdominal portion. So much so that it has been used to illustrate the appearance of a normal aorta. This simple examination permitted the assurance that no further operative treatment was necessary.

(2) Aneurysm.

Aneurysm of the abdominal aorta is usually diagnosed on clinical examination. It is not always possible to determine the type and extent of the dilatation which, however, can usually be shown by aortography.

The following three patients are examples of this condition.

Case (140) D.I. Male aged 62.

History.

This patient was admitted to a Surgical Unit on 9.11.54. He complained of fairly severe constant pain across the back and towards the left lumbar region. This had been present for six months. He had no pain in the legs.

Investigation.

A pulsatile swelling 2" in diameter was felt below and slightly to the left of the umbilicus. This was diagnosed clinically as a saccular aneurysm near the aortic bifurcation. The blood pressure was 150/100 mm./Hg., the Wasserman reaction was negative.

He was referred for aortography on 13.12.54.

The aortogram (Fig. 209) shows the needle deliberately inserted well above the site of the swelling.

This first film shows an abrupt stoppage of the dye just before it enters the aneurysm, in the lower part of the aorta.

The second film (Fig. 210) shows the dye entering the sac towards the left of the midline.

The third film (Fig. 211) shows the sac well outlined and the dye may be seen entering the common iliac arteries which are dilated.

These films were taken following two injections of dye so that the pictures were obtained at intervals of two seconds.

A diagnosis of saccular aneurysm involving the bifurcation of the aorta with displacement of the latter to the left was made.

In order to determine the relation of the sac and aorta in the antero-posterior plane, it was decided to attempt puncture with the patient lying in the lateral position. As no reference to aortic puncture in this position could be found it was not known whether it would prove difficult. In actual practice it proved quite simple, the same landmarks and technique being employed as in the usual puncture. This was carried out a week later on 20.12.54.

This lateral film (Fig. 212) shows anterior displacement of the aorta above the aneurysmal dilatation. It is interesting to note the posterior course of the renal arteries running back to the renal fossae.

The abdominal pain settled and he was discharged from hospital.

He was seen at intervals thereafter and finally on 7.6.55 excision of the aneurysm was performed, followed by a Terylene prosthesis. (W.A.M.) At operation, it was found that extensive, severe arterial disease affecting the aorta and iliac vessels was present.

Case (141) W.A. Male aged 73.

History.

This man was admitted to a Surgical Unit suffering from acute appendicitis, on 14.6.55. At operation an aneurysm of the lower part of the abdominal aorta was felt and considered to be possibly saccular.

He was referred for aortography on 5.8.55.

The aortogram (not illustrated) showed a fusiform dilatation of the aorta with considerable displacement of the main vessel and the common iliac arteries.

No surgical treatment was carried out.

The value of aortography in this case was to

demonstrate that the aneurysm was of the long fusiform rather than the saccular type.

Case (142) J.M. Male aged 83.

History.

This patient was admitted to the Urological Department on 20.10.55 for investigation of haematuria. Marked total haematuria had been present intermittently for four weeks and was associated with some dysuria and frequency of micturition.

Investigation.

On clinical examination he was a very fit man for his age. A large mass extending from just below the left subcostal area to below the umbilicus was present. It was definitely pulsatile and was considered to be a large abdominal aneurysm.

Cystoscopic examination yielded a clear urine and no intra-vesical lesion was seen to account for the bleeding. It was not considered that it was of prostatic origin. The urine was mildly infected with B. Coli and proteus.

Excretion urography on 21.10.55 was apparently normal although the calyceal detail was not very good. As no lesion of the urinary tract had been found to account for the considerable haematuria present before admission to hospital, the suspicion was raised that the swelling might be a

pulsating renal tumour. Whilst this seemed unlikely on the clinical and urographic findings it was decided to employ aortography to determine the nature of the large swelling.

This was done on 27.10.55. The first film (Fig.213) shows the needle inserted at the level of the 1st lumbar body. Above this there is obvious dilatation of the whole aorta with marked irregularity on its left side. Below this the aorta is deviated at right angles to the left and the commencing filling of the aneurysm may be seen.

The second film (Fig. 214) shows the outline of the dilated sac situated completely to the left of the spinal column and extending from the 1st to the 5th lumbar vertebrae. The needle was inserted behind the sac wall and not through it.

The patient experienced no upset from this examination which showed beyond all doubt that the condition was one of advanced abdominal aneurysm. As no further haematuria occurred it was decided not to investigate the urinary tract any further.

In view of the patient's age and the size of the aneurysm, no operative treatment was undertaken.

(3) Block.

Obstructive lesions are commonly due to athero-sclerosis and arterio-sclerosis. Similar symptoms may

be produced by spasm and it is important to differentiate between this and organic obstructive lesions.

The following two patients illustrate the value of aortography in this respect.

Case (143) N.L. Male aged 65.

History.

This man was first seen in a Surgical Unit in March 1954, complaining of pain in both legs of eight years duration. On examination, neither femoral pusle could be felt nor was there any pulsation distal to these.

In December, 1953, he developed an ischaemic ulcer of the left foot and later in March, 1954, a chemical sympathectomy in the form of a Phenol paravertebral block was carried out. Later that month he developed a coronary thrombosis and in July, 1954, a severe venous thrombosis of the left leg.

He was re-admitted to hospital on 6.12.54.

Investigation.

Clinical examination at this time showed a flexion contracture of the left hip and knee. The blood pressure was 150/70 mm./Hg. Pulsation was still absent in all vessels of the lower limbs. A clinical diagnosis of arterial block proximal to the femoral arteries was made.

X-Ray examination showed calcification near the

aortic bifurcation.

Aortography was carried out on 10.12.54.

This shows (Fig. 215) calcification in the region of the bifurcation. The major vessel entering the pelvis appears to be the superior haemorrhoidal artery. No filling of the iliac systems is seen except at one point where it is presumed to come from the middle haemorrhoidal vessel.

No operative treatment was employed but the patient derived some benefit from rest, massage, exercises and anti-coagulant therapy.

Case (144) F.G. Male aged 29.

History.

This man was admitted to a Surgical Unit on 24.4.55. He complained of pain in both legs of four years duration.

Investigation.

On clinical examination this patient had a long body with a "funnel chest". The leg pains were of a cramping nature, worse after exercise. The femoral pulses were normal.

He was referred for aortography on 6.5.55.

The first puncture was carried out rather high with the result that much of the dye entered the renal and superior mesenteric vessels. A second puncture was therefore made at a lower level with satisfactory results. This film which is not illustrated showed the aorta and iliac vessels to be

normal in all respects. It was considered that this patient was an example of "central claudication" due to displacement of the heart by the deep funnelling of the chest.

On 30.5.55 a plastic operation was carried out on the thoracic cage. (W.A.M.)

The value of aortography in this case lay in proving the absence of intrinsic vascular disease which might have been amenable to direct surgery.

ILIAC ARTERIES.

Obliterative lesions affecting these vessels have been divided into those of the common iliac and those of the external iliac arteries. This distinction is made for descriptive purposes but in a number of instances the lesions were widespread and affected not only these two vessels but also the internal iliacs as well.

Common Iliac Artery Blockage.

There were six patients in whom these vessels were mainly affected.

Case (145) R.L. Male aged 54.

History.

This man was admitted to a Surgical Unit in December, 1953. He had suffered from cramping pains in the lower limbs since 1951. In January, 1952, lumbar sympathectomy had been performed but in March, 1953, it was found necessary to perform amputation through the lower third of the left thigh.

When seen at the end of 1953, he complained of severe pain in the right calf after walking 10-15 yards.

Investigation.

On clinical examination the stump of the left thigh was cold and there was obvious deficient circulation, the left femoral pulse being imperceptible. On the right side the femoral pulse was almost imperceptible although the oscillometer showed a reasonably satisfactory but damped wave in both the thigh and calf.

Aortography was performed on 22.1.54.

This shows (Fig. 216) complete occlusion of the left common iliac artery at its origin. There is partial occlusion of the right common iliac artery due to atheromatous intrusion on the medial aspect. This shows as a filling defect with a rounded margin.

Operation.

Disobliteration of the right common iliac artery was carried out on 8.2.54. (W.A.M.)

The lesion seen in the aortogram was easily exposed and it was found that the lumen of the right common iliac artery was virtually obliterated proximal to its bifurcation. The lesion was more extensive than the aortographic findings suggested.

Histology confirmed extensive atheroma of the intima.

Case (146) J.W. Male aged 50.

History.

This man was first seen on 27.1.54. Two years previously he had suffered a sudden numbness which affected the right leg and foot. Thereafter his walking distance was restricted to 100 yards.

Investigation.

On clinical examination there was marked flexion contracture of the right knee. There was obvious circulatory disturbance and both feet were cold, the right being apparently more affected than the left. The left femoral pulse was perceptible but all other pulses of both limbs were absent. He was referred for aortography on 5.2.54.

This shows (Fig. 217) that there is a complete block at the origin of the right common iliac artery. The collateral circulation is through the lowermost lumbar artery, the arteria lumbalis ima of the middle sacral and the ilio-lumbar branch of the internal iliac artery.

On the left side there is a definite stenosis due to a smooth V shaped intrusion of the common iliac artery. The distal filling of the main vessel, however, is good.

This patient had a paravertebral block with good results but no further details are available as he has failed to report back.

Case (147) A.H. Male aged 52.

History.

This man was admitted to a Surgical Unit on 24.7.55. He had suffered intermittent pain in the left leg for the previous two years.

Investigation.

On clinical examination, marked claudication was present, his walking distance being reduced to 100 yards. There was paraesthesia of the left foot. On the right side, pulsation was present in the femoral artery and possibly in the popliteal but absent distal to this. On the left side no pulsation was present in the femoral or distal arteries.

A clinical diagnosis of blockage of the left iliac vessels was made. He was referred for aortography on 29.8.55.

This shows (Fig. 218) that there is a complete obstruction in the left common iliac artery at its origin.

In addition, there is marked irregularity affecting the right common iliac artery and its internal branch.

Subsequent films (Fig. 219) showed retrograde filling from the internal pudendal and superior gluteal vessels.

No surgical treatment has yet been performed.

Case (148) J.K. Male aged 58.

History.

This army officer was first seen in a Surgical Unit on 2.6.54. He had suffered severe pain in both calves of the legs for the previous eighteen months. This was more marked on the right side and his painless walking distance was reduced to some 5 yards.

Investigation.

On clinical examination he was of slight build. Marked varicosity of the veins of both legs was present. The muscles of the right calf and foot were wasted and trophic changes affected the toes on that side. Bilateral phenol paravertebral block was carried out at that time with no significant improvement.

He was admitted to hospital on 28.7.54.

On clinical examination the vascular changes previously noted were still present. Both femoral pulses were felt but below this no pulsation was found. He was referred for aortography on 8.8.54.

This shows (Fig. 220) marked arterio-sclerosis affecting the main vessels. Whilst there is considerable

irregularity of both external and internal iliac arteries there is no gross stenosis or obstruction of these vessels. These appearances suggested that direct surgical treatment was not indicated and therapy consisting of intra-arterial injections of papaverine hydrochloride was administered.

Case (149) T.O'D. Male aged 62.

History.

This man was admitted to a Surgical Unit on 21.6.55. He complained of severe cramping pains affecting the right leg of six months duration. His walking distance was reduced to 20 yards.

Investigation.

On clinical examination, marked nutritional changes were present affecting the right foot and there was wasting of the thigh and calf muscles on that side. No pulses were present in the right lower limb whilst on the left side pulsation was present in the femoral and popliteal arteries.

The posterior tibial pulse was doubtful on the left side and the dorsalis pedis was absent.

Oscillometry showed 1 u. in the right thigh and 10 u. in the left. Below the knee it registered 0.5 u. on the right and 2 u. on the left.

A clinical diagnosis of blockage of the right iliac vessel with probable blockage below the left popliteal artery

was made.

He was referred for aortography on 25.7.55.

This shows (Fig. 221) marked stenosis of the right common iliac artery, with blockage of the external iliac artery on that side.

Right lumbar ganglionectomy was performed on 11.8.55, the 2nd and 3rd lumbar ganglia being removed. (W.A.M.) No material benefit accrued from this operation and he was re-admitted to hospital on 25.10.55.

Oscillometry on this occasion showed on the left side 14 u. above the knee and 1.5 u. in the calf. On the right side it showed no visible recordings above or below the knee.

Aortography was repeated on 2.11.55.

This shows (Fig. 222) that there is now complete blockage of the right common iliac artery.

Case (150) T.N. Male aged 56.

History.

This man was admitted to a Surgical Unit on 14.10.55. Three years previously he had suffered a sudden pain in the right leg which was diagnosed as "complete blockage of an artery." The pain had been present with varying intensity since that time and he was unable to walk more than 100 yards without severe discomfort.

Investigation.

On clinical examination he appeared to be a fairly healthy stout man. The blood pressure was 170/90 mm./Hg. The right leg and foot were colder than the left. All pulses were present in the left lower limb but on the right side pulsation was present in the femoral artery but absent distal to it.

Oscillometry above the knee showed 3 u. on the right side and 7 u. on the left. Below the knee the readings were 1 u. right and 6 u. left.

Aortography was carried out on 14.10.55. The films (not illustrated) suggested that there was a partial occlusion of the right common iliac artery near its origin. There appeared to be a satisfactory blood flow into the main vessels beyond this and no surgical treatment was carried out.

Case (151) L.M. Male aged 63.

History.

This patient was admitted to a Surgical Unit on 30.8.55. He complained of severe cramping pains in the legs of some two years duration. Although the pain appeared to be more severe on the left side he had also suffered similar cramping pains on the right side and his walking distance was reduced to less than 100 yards.

Investigation.

The circulation of the left leg appeared to be fairly satisfactory, the femoral pulse being quite prominent and those below this level being palpable. On the right side, it was doubtful whether the femoral pulse was present nor could the popliteal, posterior tibial or dorsalis pedis pulses be felt. Oscillometry showed that below the knee 10 u. was registered on the left side and only 3 u. on the right.

Aortography was performed on 31.8.55. This shows (Fig. 223) athero-sclerosis affecting both common iliacs, the changes being more marked on the right than on the left side. There is apparent obliteration of the internal iliac arteries.

In view of the bilateral nature of the disease shown on aortography, no surgical treatment was carried out.

External Iliac Blockage.

The following two patients are examples of marked obliterative changes affecting mainly the external iliac arteries.

Case (152) J.M. Male aged 54.

History.

This patient was first seen in a Surgical Unit on

24.8.54. He had suffered a sudden pain in the right thigh nine days previously. Since then the right lower limb had felt cold and his walking distance had been reduced to 20 yards.

Investigation.

On clinical examination, no pulse was palpable anywhere in the right lower limb. The left leg appeared to be normal. The blood pressure and electrocardiogram were normal.

He was referred for aortography on 6.10.54.

This shows (Fig. 224) that there is a stenotic funnelling of the origin of the right external iliac artery. There is a block below the inferior epigastric and deep circumflex iliac vessels. The right superficial femoral artery is filled poorly, the anastomosis being produced by the internal pudendal and obturator branches. (Fig. 225)

There is also an atheromatous plaque in the left common femoral artery.

Right lumbar ganglionectomy was performed on 2.11.54. (W.A.M.)

Case (153) R.M. Male aged 64.

History.

This man was admitted to a Surgical Unit on 15.4.53. He complained of severe pain affecting the right leg of six months duration. His walking distance was reduced to 5 yards.

On examination, the right leg was found to be colder than the left and no pulsation was present in any of the arteries of the right lower limb. On 21.4.53, a right paravertebral block was performed.

He was re-admitted to hospital on 9.9.54, complaining of pain in the left calf as well as the right.

Investigation.

On clinical examination the patient appeared to be a fairly fit man. The toes of the right foot showed nutritional skin changes associated with obliterative vascular disease. The right femoral pulse was faint but present, no pulses being felt, however, below this.

On the left side the femoral pulse was of good volume but no pulsation could be felt in the leg below this level.

He was referred for aortography on 13.9.54.

This shows (Fig. 226) gross arterio-sclerosis obliterans. There is marked stenosis of the right common iliac at its origin and complete blockage at the upper end of the right external iliac artery. Minimal filling of the right femoral artery is derived from the superior gluteal and obturator arteries round the hip joint.

On the left side, arterio-sclerotic changes are also present but although there is a narrow constriction of the external iliac there is direct filling of the common femoral

artery below this point.

In view of the bilateral nature of the disease shown on arteriography no surgical treatment was carried out.

FEMORAL ARTERY.

There were five patients who displayed evidence of vascular disease of the femoral arteries.

One patient had an obvious aneurysm whilst the remaining four had intrinsic vascular disease causing obstruction.

Aneurysm.

The following case is an example of aneurysm affecting the upper part of the femoral artery.

Case (154) M.C. Male aged 56.

History.

This patient was admitted to a Surgical Unit on 18.10.55. He complained of swelling in the left groin which had first appeared two years previously. This swelling had recently become larger but was not associated with pain or any

appreciable disability affecting the left leg.

Investigation.

On examination, a soft pulsatile swelling some 3 x 2 in. was seen in the groin. It appeared to be almost bisected by the inguinal ligament which was stretched over it. There did not appear to be any slowing of the blood stream below this level as all pulses in the left limb were palpable.

He was referred for aortography on 24.10.55.

This shows (Fig. 227) an ovoid aneurysm overlying the head of the left femur and arising at the origin of the left femoral artery. It is apparently situated on the medial side of this vessel which it has displaced laterally.

Although diffusion of dye has occurred so that the definition is rather poor, the shape and limits of the aneurysm are clearly defined.

On 31.10.55, the aneurysm was excised and a reconstructive operation performed, using a freeze-dried graft. (W.A.M.)

At operation, it was interesting to find that the arteria profunda femoris opened directly into the sac.

The subsequent progress of this patient has been satisfactory.

Stenosis.

The following four cases are examples of obstructive lesions affecting the femoral artery at various levels.

Case (155) G.M. Male aged 56.

History.

This man was admitted to a Surgical Unit on 12.10.54. He complained of severe cramping pains in the right calf of 15 months duration. His walking distance was reduced to 300 yards.

Investigation.

On clinical examination he was a sparely-built man who looked quite healthy. The blood pressure was quite normal. All pulses were present in the right lower limb with the exception of the dorsalis pedis artery. On the left side the common femoral pulse was present but no other below this level. The left foot felt colder than the right but no nutritional skin changes were present.

He was referred for aortography on 23.10.54.

On this occasion, the first film (Fig. 228) was taken following the usual technique. In order to obtain better filling, a second film (Fig. 229) was taken after compression of the right femoral artery.

These films show that the whole of the left superficial femoral artery is grossly narrowed, especially in

the lower third at the site of obvious calcification. There is a striking difference between the superficial femoral and the profunda femoris artery, the latter showing practically no vascular abnormality.

On the right side, similar though less marked changes affect the superficial femoral artery.

Left lumbar sympathectomy was performed on 10.12.54 (W.A.M.) with good immediate result, the dorsalis pedis pulse being palpable several months later.

Case (156) J.R. Male aged 58.

History.

This man was admitted to a Surgical Unit on 14.7.54. He complained of cramp-like pains in the right calf of fifteen weeks duration. He had also experienced similar pain in the left calf for the three weeks previous to admission.

Investigation.

On clinical examination marked varicosity of the veins of the left leg was present and there was wasting of the left calf muscles. Both femoral and popliteal pulses were present on each side but there was doubt regarding the posterior tibial pulses, whilst the dorsalis pedis was definitely absent on the right side.

A right femoral arteriogram performed on 24.7.54 showed a block about 1" in length in the superficial femoral

artery immediately proximal to the adductor opening.

A disobliterative operation was performed on 2.8.54 on the right side. (W.A.M.) This was successful and on 2.11.54 all pulses were present in the right lower limb and the patient was free from pain.

On the left side, however, no pulses were present below the femoral artery and he complained of the limb feeling heavy and tired.

He was referred for aortography on 12.11.54.

This shows (Fig. 230) that the right superficial femoral artery is now patent and that there is only slight narrowing at the site of previous obliteration.

On the left side, there is a hold-up of the dye at the adductor opening.

A femoral arteriogram on 8.12.54 showed the block to be in the popliteal artery and on 13.12.54 a disobliterative operation for this was performed with good result. (W.A.M.)

Case (157) R.R. Male aged 49.

History.

This man was admitted to a Surgical Unit on 27.10.54. He complained of pain in the right leg which had been present for a year. The claudication had been more marked in the last three months and his walking distance reduced to 100 yards.

Investigation.

On clinical examination he appeared to be a fairly healthy man. The right leg and foot felt colder than the left. The right femoral pulse was present but all pulses distal to this were absent.

He was referred for aortography on 3.11.54.

This shows (Fig. 231) occlusion of the right superficial femoral artery from the mid-thigh downwards.

On 5.11.54 a right lumbar paravertebral block was carried out and followed by intra-arterial papaverine injections. The response to this was not satisfactory and it was necessary to perform amputation below the knee on 26.5.55. (W.A.M.)

Case (158) H.M. Male aged 56.

History.

This man was admitted to a Surgical Unit on 10.11.54. For three years he had suffered claudication affecting both legs. This had become worse in the last three months and his walking distance was reduced to 100 yards.

Investigation.

The right foot felt colder than the left but no pulse was present in either posterior tibial or dorsalis pedis arteries. The pulses above this level on each side were present.

He was referred for aortography on 12.11.54.

Initial puncture was not satisfactory so a second puncture was made before injection of the dye.

The arteriogram shows (Fig. 232) arterio-sclerotic irregularity of the iliac vessels and a well-defined constriction near the origin of the right common femoral artery.

Femoral arteriography on 16.11.54 showed a degree of occlusion lower in that vessel.

Right lumbar ganglionectomy was performed on 22.11.54. (W.A.M) At operation evidence of blood extravasation, from the aortic puncture, was found but was not considered excessive. It did not interfere with the identification or removal of the ganglion.

The result of this operation proved satisfactory.

SUMMARY AND CONCLUSIONS.

Translumbar aortography was carried out on twenty patients with real or suspected vascular disease affecting the aorta, iliac or femoral arteries.

In eighteen of these, advanced organic disease was present in the main arteries and it is not unreasonable to suppose that similar changes affected the aorta in a number of them.

In spite of this, aortic puncture - perhaps even through an atheromatous plaque - was not attended by any serious haemorrhage. One patient (Case 158) who required two punctures, showed evidence at operation of some bleeding around the aorta but this did not appear to be greater than that which might occur following puncture into a normal, healthy vessel.

None of the twenty patients, including the above, displayed any clinical signs or symptoms of bleeding or any other complication.

Translumbar puncture was performed in three cases of aortic aneurysm and it is considered that this method is safe and has advantages over that of retrograde femoral catheterisation.

A second puncture in the lateral position in Case (140) was effected with ease and no ill effect, although

extensive aortic disease was confirmed at operation. This method of obtaining lateral films has been shown to be quite feasible and affords complete information regarding the size, shape and position of the aneurysm, especially the saccular type.

A further patient (Case 149) had a second puncture within three months without any complications.

Case (156) illustrates the value of post-operative visualisation in which, by one examination, patency of the right side and obstruction on the left was shown.

In every case information, valuable from the diagnostic or operative point of view, was obtained.

The method of low puncture and rapid injection provided radiological definition of the abdominal and pelvic vessels of a high standard and equivalent to that of the peripheral vessels obtained by peripheral arteriography.

The indications for the use of translumbar aortography for these major vessels are the same as those summarised by Learmonth for the demonstration of the more distal vessels of the limbs.

Whilst the surgery of the aorta and iliac vessels is more formidable than that of the smaller arteries and the consequences of poor results more serious, successful operative treatment carries a proportionate benefit. The direct visualisation of these major arteries is a necessary

and invaluable part of the investigation, whether or not operation is performed.

Intrinsic vascular disease frequently involves more than one arterial segment and the greater the extent of the vascular tree outlined the greater the opportunity of determining the presence or absence of multiple lesions. In addition to this aortography enables comparison to be made between the vascular channels of each side.

At the present time it is seldom used for definition below the level of the femoral artery, mainly because of the difficulties in judging the exposure and covering such a large field. This is largely a technical difficulty.

It is felt that with improvements in fast serial photography, synchronised with a moving tube, the ideal of a complete record of the aorta and all the vessels of both lower limbs can be achieved.

TUMOURS OF BONE.

In his early reports dos Santos (1929, 1934) described the value of arteriography in studying the patency and pattern of vascular systems in the viscera and limbs. Later, he employed a technique of serial arteriography, taking films every two seconds, to ascertain the functional circulation of normal and diseased tissues of limbs.

In 1950 he recorded the results of this investigation carried out in conjunction with Caldas, on 100 cases of lesions of bone and soft tissue.

Apart from vascular disease, these included inflammatory and neoplastic conditions and the diagnostic angiographic changes were described.

Acute inflammatory lesions were associated with exaggerated vascular activity in which the vessels retained an orderly and regular arrangement.

Chronic osteo-myelitis, on the other hand, showed relative ischaemia at the level of the bone lesion.

Malignant tumours of bone and soft tissue, such as sarcoma, presented an irregular formation of new vessels and vascular pooling.

Simple tumours showed no new formation of vessels and frequently were found to be relatively avascular.

These studies, however, were done for peripheral

lesions and intra-arterial as opposed to intra-aortic injection was made. Further, the medium used was Thorotrast. This compound of Thorium dioxide is a radio-active substance and its use has been condemned in this country except for animal experiments. It is not eliminated by the kidneys but is stored in the liver and spleen. Apart from this disadvantage in renal angiography the quantity which would require injection into the aorta for any purpose is considered far beyond the safety margin for use in the human.

The arterial changes described by dos Santos occurring in bone and soft tissue may, however, be shown by the organic iodide compounds, although these do not produce such satisfactory definition and concentration in the venous return.

Begg (1955) described similar angiographic changes in six cases of bone lesions in which peripheral arteriography was carried out using Diodone.

He quoted a personal communication from R.M.Walker who found that in fifty-five out of five hundred and seventeen cases from the Bristol Bone Tumour Register, the diagnosis still remained debatable after careful clinical, radiological and biopsy examinations.

Begg considered that angiography provided useful information in a positive and negative way and assisted both the diagnosis and form of treatment. He suggested also that

it was superior to biopsy by preventing possible dissemination of the tumour.

The opportunity has arisen of examining one case only of bone tumour. This was a sarcoma of the right ilium and it was obvious that intra-aortic injection was necessary in this case. The technique of low aortography with 70% Sodium Acetrizoate was used.

Case (159) W.G. Male aged 21.

History.

This young man sustained an injury to the right hip bone whilst working with the coupling of a tractor. After the initial severe pain subsided he suffered fairly constant pain and tenderness over the iliac crest. This did not lessen in the succeeding weeks and was still sufficient to cause him to limp.

On 8.11.55, four weeks after the accident he was sent to a Surgical Unit for examination.

This revealed tenderness over the right iliac crest with some associated muscle spasm. X-Ray examination of the bony pelvis showed no evidence of injury or any other abnormality. He was examined a week later with similar results and again it was considered that no bone abnormality was shown on X-Ray examination.

The pain persisted in the form of a dull ache and occasional shooting pains down the right leg. Further examination on 23.11.55 still confirmed tenderness and some swelling over the bone which now showed on X-Ray "an osteolytic process involving the right ilium below the crest, the appearances being those of a large bone tumour, probably sarcomatous."

He was admitted to hospital on 7.12.55

Investigation.

There was definite fullness of the tissues overlying the right iliac crest and the upper part of the right thigh. Tenderness and muscle guarding were quite marked in those regions.

A biopsy of bone was taken on the following day. Histological examination showed "invasion of skeletal muscle by a malignant anaplastic tumour. The tumour cells are broken up by strands of connective tissue containing well-formed blood vessels. Tumour cells appear to be within thin-walled vessels. There is no intercellular material typical of osteoid tissue but the tumour could have arisen from bone."

Before this pathological result was available he was referred for aortography on 9.12.55.

Low puncture was easily effected and a satisfactory film obtained. It was thought desirable to carry out a second injection to obtain later films. Some difficulty was

encountered in connecting the new tubing during which some dislodgement of the needle occurred. The second injection produced extravasation which was followed by marked abdominal pain and distension which persisted for 24 hours. This, however, was relieved by and responded to sedation.

Reference has been made to this when discussing the hazards of aortic injection.

It is interesting to find that in this case of low puncture, dye extravasation caused more upset than those cases where it occurred with a high puncture. It had been assumed that such irritative effects would have been more marked around the coeliac plexus than lower in the abdomen.

The arteriogram (Fig. 233) shows considerable enlargement of the nutrient vessels to the affected area of tumour formation in the right ilium. The ilio-lumbar branch of the posterior trunk of the internal iliac artery may be seen running up and along the iliac crest to supply the tumour from the superior aspect. The nutrient vessels from the inferior aspect consist of the superior gluteal artery which is considerably dilated and the deep circumflex iliac branch of the external iliac artery.

The tumour area itself consists of an intense vascular bed below the iliac crest in its lateral part. There is considerable irregular formation of new arteries with a degree of pooling in the centre of the area.

These appearances correspond to those described by dos Santos and Begg as diagnostic of bone sarcoma.

No operative treatment was carried out on this patient but a full course of radio-therapy has been given with satisfactory immediate effect.

SUMMARY AND CONCLUSIONS.

One case of bone sarcoma has been investigated by aortography and the angiographic changes clearly demonstrated. These consist of increased arterial vascularity of an irregular pattern within the tumour area, the nutrient vessels of which show obvious enlargement.

Whilst the diagnosis in this case was made on other examinations, angiography when performed was as definite as any of these.

A serious condition such as bone sarcoma requires extensive surgical or irradiation treatment and it is essential to establish the true nature of the condition before embarking on such radical treatment.

Whilst further experience is necessary to assess the value of angiography in the early stages of bone neoplasm there

appears to be no doubt that it offers a further useful and safe method of diagnosis in the established lesion. In this respect, translumbar aortography is considered to be as safe and accurate as peripheral arteriography.

CONCLUSION.

An historical review has been given of the development of X-Ray visualisation of arteries from the early days of Röntgen to the present time.

This thesis deals particularly with translumbar aortography and its application in diagnosis.

An account has been given of original experimental work in connection with the anatomical and physiological factors involved in intra-aortic injection.

A technique has been described whereby rapid injection of opaque medium may be carried out with safety and the production of accurate, clear pictures.

A description and discussion of the hazards and results obtained in a personal series of two hundred aortic punctures has been given.

The angiographic findings in various specific conditions are described in detail and a summary and conclusions based on these findings has been included at the end of each section dealing with each specific condition.

The main bulk of the work is based on pathological conditions affecting the kidneys. It is considered that renal angiography now has an established place in the diagnosis and management of many such conditions.

The superiority of angiography over urography in

certain circumstances does not imply that these older established methods should be abandoned. Angiography is supplementary to urography and does not replace it, nor should it be regarded as a routine examination. The procedure should only be undertaken when such special information is necessary and then only by trained personnel.

Aortography has an application beyond lesions affecting the urinary tract. It is a necessary part of the investigation of many cases of intrinsic vascular disease and has also a contribution to make in connection with lesions of bone and soft tissue.

It has been shown how, over a period of sixty years, there has developed from the primitive pictures of cadavers a reasonably safe and justifiable method of visual diagnosis of practical application in the living human.

Much remains to be done. Further advances in the sphere of fast photography and cine-radiography, more effective and safer injection media and refinements in technique are necessary and inevitable.

A completely new field of radio-diagnosis of the abdominal organs and blood vessels has been opened up but, as yet, too few cases have been done to permit a full appreciation of its value. At present, one of the greatest difficulties lies in the interpretation of results. This difficulty will be overcome in time as aortography becomes more general.

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AORTOGRAPHY IN DIAGNOSIS

VOLUME THREE

ILLUSTRATIONS

C O N T E N T S

VOLUME III

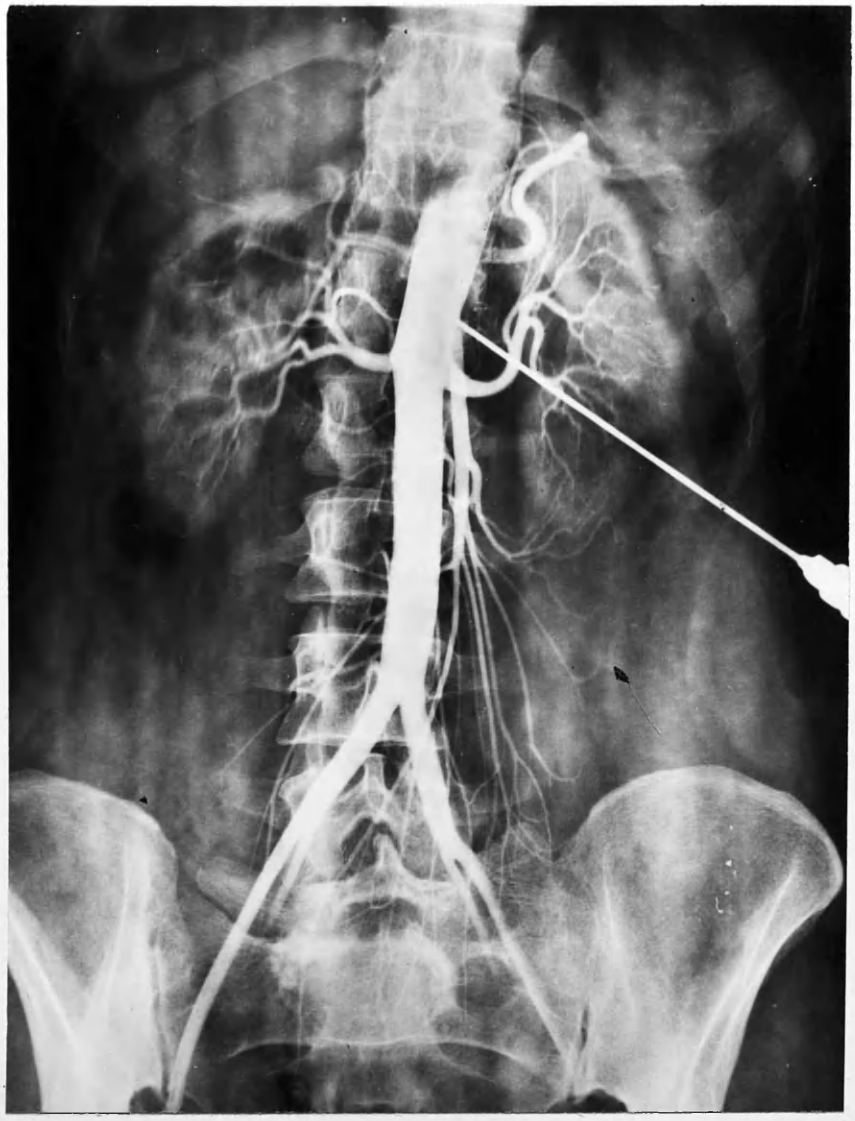

Fig. 1 Case 139

Normal Aortogram.

Arteriogram shows Phase I. Sodium Acetrizoate 70% 18 ml. injected in 1 sec.

Fig. 2 Case 44.

Normal Nephrogram.

Nephrogram shows Phase II, 4 sec. after injection.

Fig. 3 Page 87.

Excretion Urogram.

Late excretion shows Phase III - 10 min. after injection. This is equivalent to the effect produced by the usual intravenous method.

Fig. 4 Case 3.

Extra-aortic Extravasation.

First puncture produced extensive para-aortic extravasation - 15 ml. Urokon.

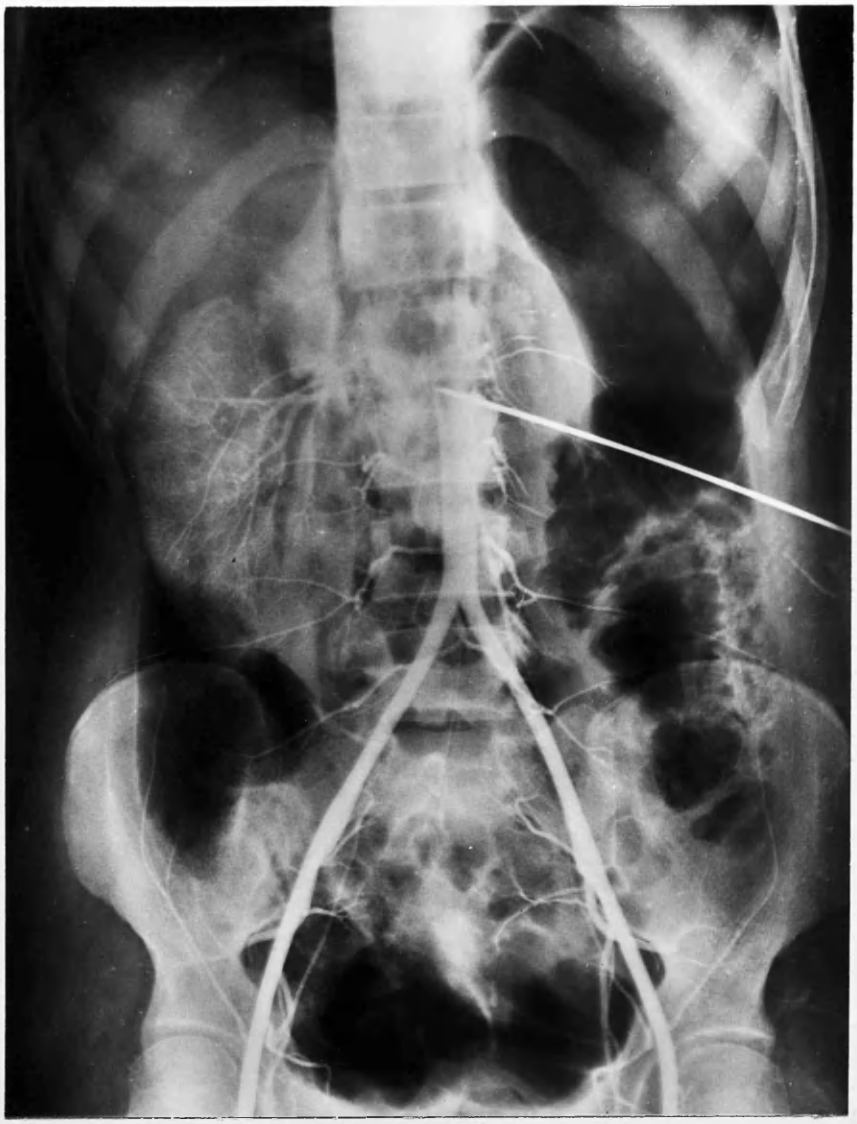

Fig. 5 Case 3.

Extravasation.

Second puncture 10 min. after extravasation.
Although definition of right renal artery is not good it is sufficient for diagnosis.

Fig. 6 Case 43.

Intra-mural extravasation.

Arteriogram shows localised intra-mural extravasation. Most of the dye, however, has entered the lumen of aorta.

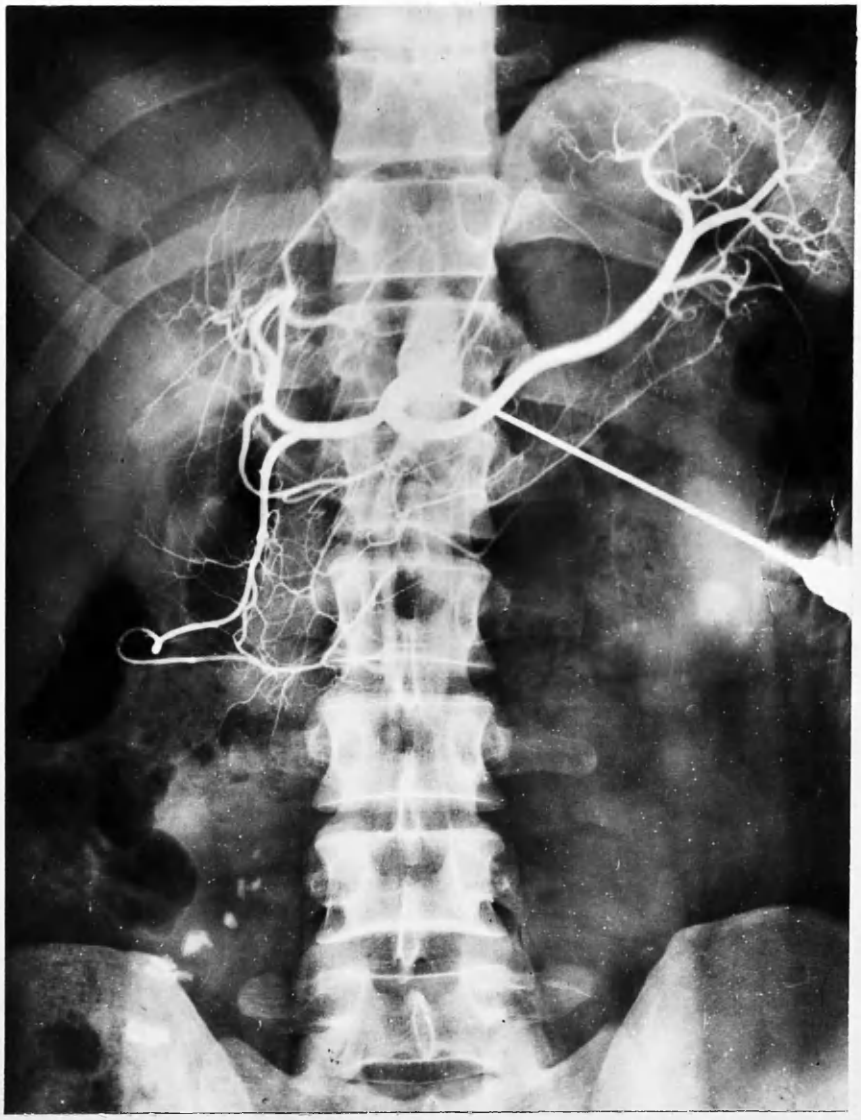

Fig. 7 Case 19.

Injection into one branch.

Injection wholly into coeliac axis. The blood supply of the liver, spleen and stomach is well outlined.

Fig. 8 Page 109.

Injection into one branch.

Injection mainly into right renal artery, producing immediate dense nephrogram effect.

Fig. 9 Case 1.

Congenital Solitary Kidney.

Arteriogram shows normal blood supply to right kidney. There is complete absence of any arterial segment on the left side. The aortic wall is smooth and unbroken.

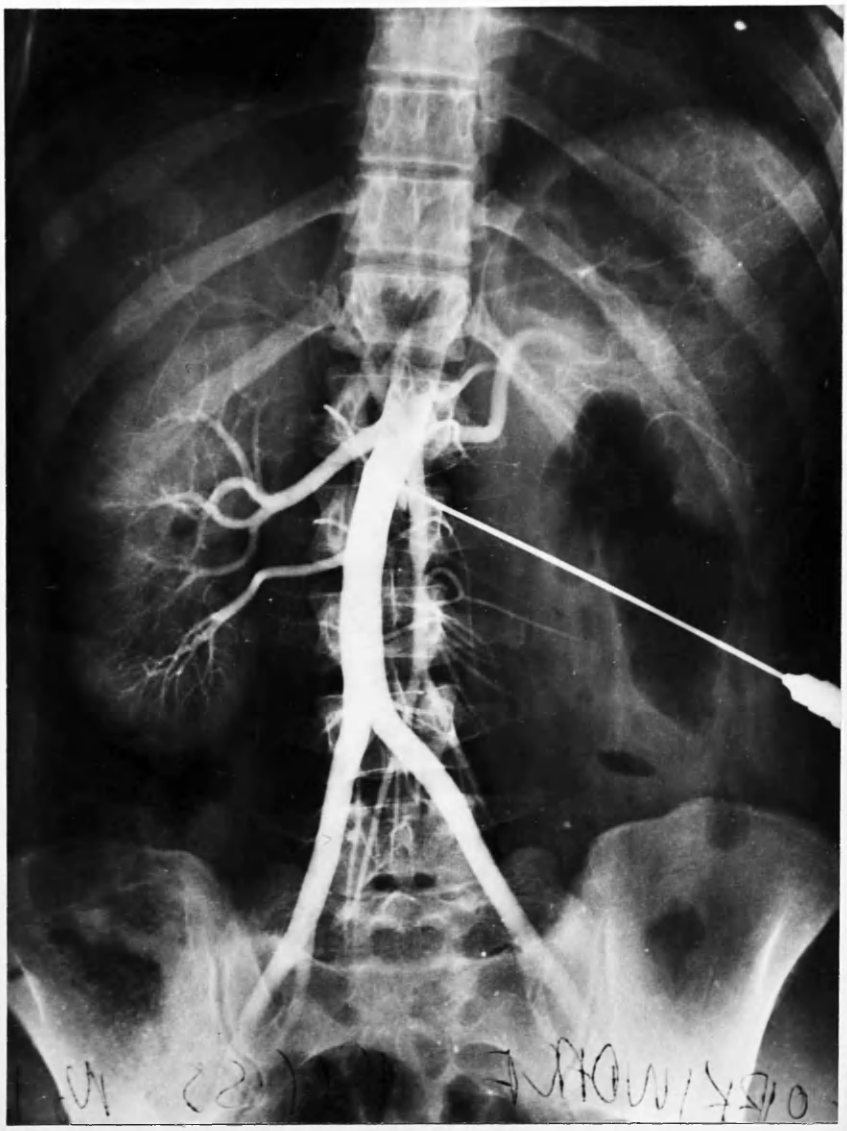

Fig. 10 Case 2.

Congenital Solitary Kidney.

Arteriogram shows double blood supply to solitary right kidney. Complete absence of renal artery on the left side where the aortic wall is regular and unbroken.

Fig. 11 Case 2.

Congenital Solitary Kidney.

Nephrogram outlines a large normal right kidney.
No renal tissue on the left side.

Fig. 12 Case 4.

Congenital Solitary Kidney.

Arteriogram shows complete absence of right renal artery. The aortic wall on that side is smooth and regular.

Fig. 13 Case 4.

Congenital Solitary Kidney.

Bilateral ascending pyelogram shows dye has not risen above iliac crest in the right ureter.

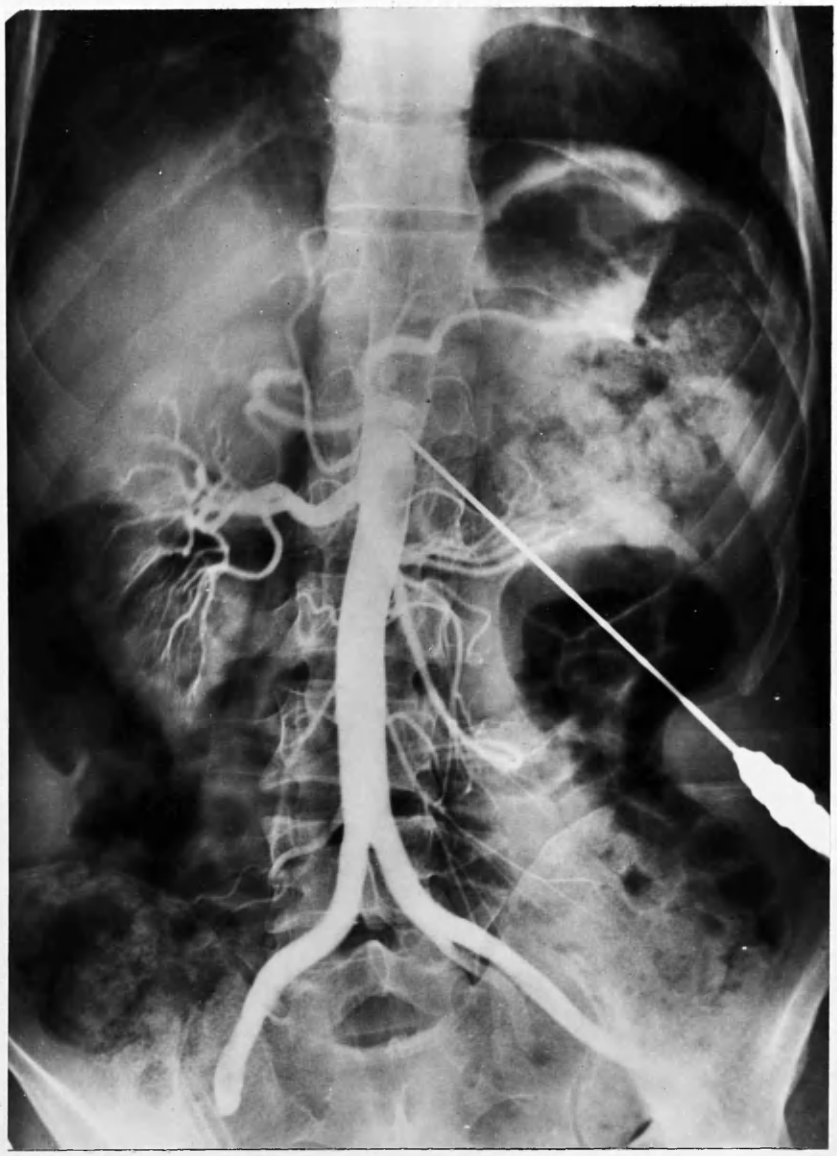

Fig. 14 Case 5.

Congenital Solitary Kidney.

Arteriogram shows absence of left renal vascularity. The right renal artery is hypertrophied.

Fig. 15 Case 6.

Abdominal Renal Ectopia.

Arteriogram shows double blood supply to low-lying right kidney. Accessory artery to lower pole runs straight across from the aorta.

Fig. 16 Case 6.

Abdominal Renal Ectopia.

Nephrogram shows position and outline of ectopic right kidney. There is some degree of foetal polar approximation.

Fig. 17 Case 7.

Unilateral Renal Pelvic Ectopia.

Arteriogram shows blood supply to ectopic left kidney to derive from aorta just above its bifurcation.

Fig. 18 Case 7.

Unilateral Renal Pelvic Ectopia.

Nephrogram defines size, shape and position of ectopic left kidney.

Fig. 19 Case 8.

Bilateral Renal Pelvic Ectopia.

Arteriogram shows renal arteries arising from aorta which has a high bifurcation. The course and distribution of the arteries is clearly shown.

Fig. 20 Case 8.

Bilateral Renal Pelvic Ectopia.

Nephrogram shows the size, shape and relation of the fused kidneys overlying the sacrum.

Fig. 21 Case 9.

Unilateral Malrotation.

Ascending pyelogram shows low-lying dilated left kidney. One calyx points medially whilst remainder and pelvis are directed anteriorly.

Fig. 22 Case 9.

Unilateral Malrotation.

Arteriogram shows double supply to left kidney. The lower accessory artery arises at level of L.IV.

Fig. 23 Case 9.

Unilateral Malrotation.

Nephrogram shows poor density of left kidney which is of normal size and shape but with hilum facing laterally.

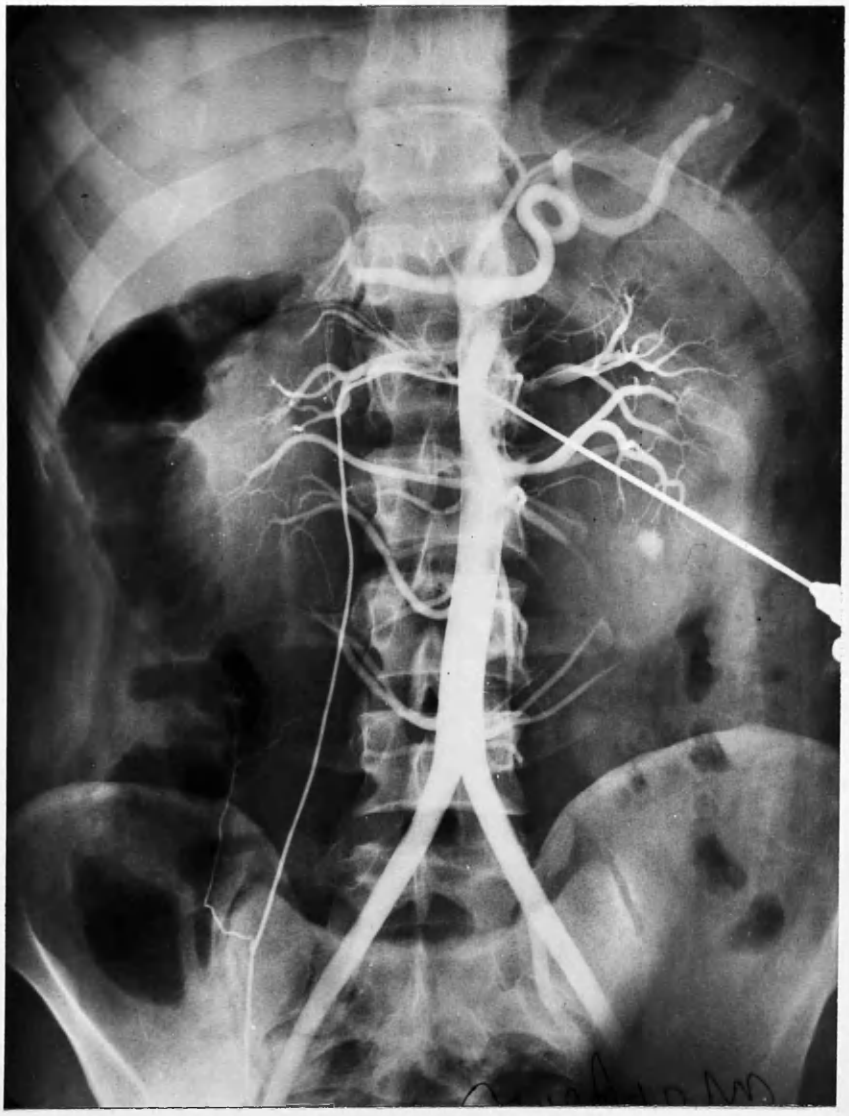

Fig. 24 Case 10.

Bilateral Incomplete Rotation.

Arteriogram shows four right and three left renal arteries. Note also right spermatic artery and stone in left kidney.

Fig. 25 Case 10.

Bilateral Incomplete Rotation.

Nephrogram clearly shows the parenchymal outline. Lower pole fusion is not present.

Fig. 26 Case 11.

Horseshoe Kidney.

Arteriogram shows, in addition to normal renal arteries, symmetrical accessory vessels to the isthmus and lower poles. These arise from the medial aspect of the aorta just above its bifurcation and run behind the iliac arteries.

Fig. 27 Case 11.

Horseshoe Kidney.

Nephrogram shows median fusion of the kidneys. Note marked medial obliquity of lower halves of each kidney.

Fig. 28 Case 12.

Horseshoe Kidney.

Nephrogram shows parenchymal outline. Each half is approximately equal with median fusion overlying L.III and IV.

Fig. 29 Case 13.

Horseshoe Kidney.

Arteriogram shows one renal artery on the right side and two on the left. The lower left artery bifurcates near the aorta and supplies both right and left portions of the fused renal tissue.

Fig. 30 Case 13.

Horseshoe Kidney.

Nephrogram shows asymmetrical fusion. The left half resembles a normal kidney whilst the right lies almost transversely across the vertebral column.

Fig. 31 Case 14.

Crossed Renal Ectopia.

Arteriogram shows right renal artery arising at level of L.III. The left artery arises from the aortic bifurcation and runs parallel to the displaced right common iliac to supply the left kidney which is displaced to the right iliac fossa.

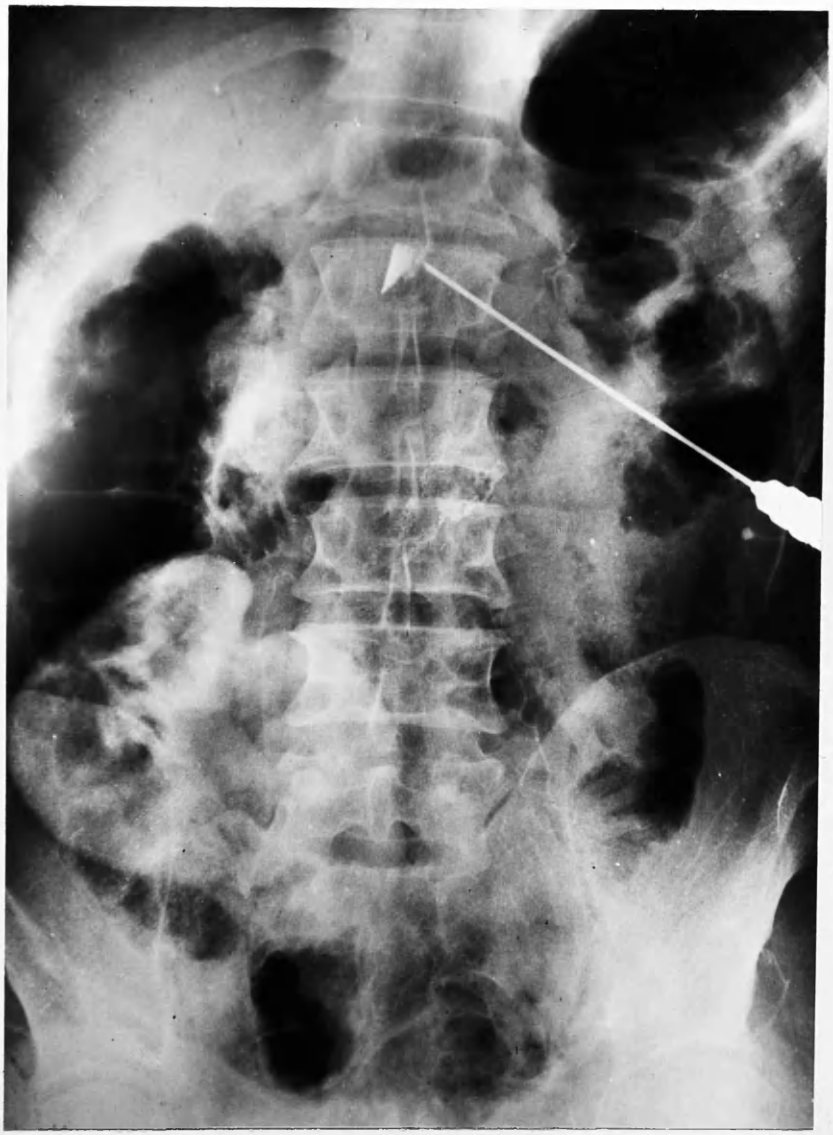

Fig. 32 Case 14.

Crossed Renal Ectopia.

Nephrogram shows fusion of the kidneys along their medial borders.

Fig. 33 Case 15.

Crossed Renal Ectopia.

Arteriogram shows right renal artery arising at level of L.III. The left arises from the aorta just above its bifurcation which is high.

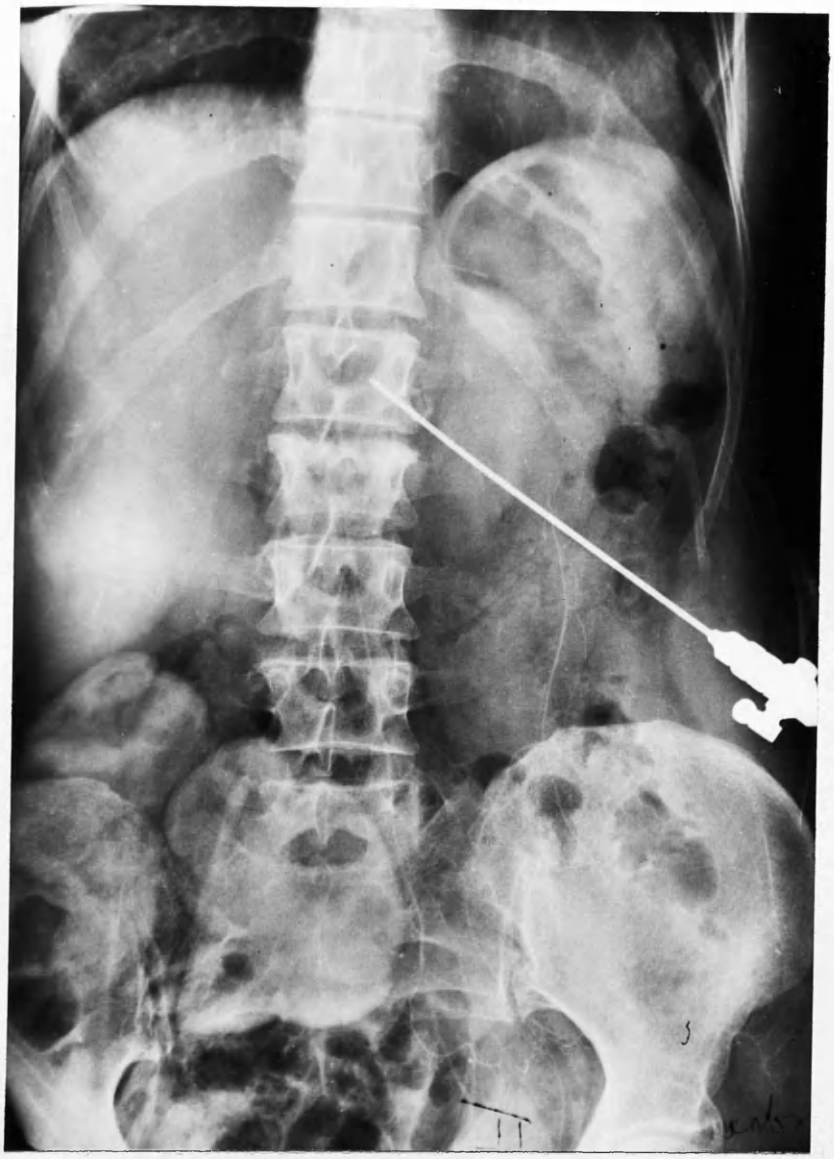

Fig. 34 Case 15.

Crossed Renal Ectopia.

Nephrogram shows fusion of the kidneys at an acute angle, the upper pole of the left being joined to the hilum of the right.

Fig. 35 Case 16.

Crossed Renal Ectopia.

Arteriogram shows three renal arteries on the left side. One renal vessel arises from the right side of the aorta and crosses it to supply the lower part of the fused left renal tissue.

Fig. 36 Case 16.

Crossed Renal Ectopia.

Nephrogram shows fused renal tissue to consist of a hypertrophied, elongated left kidney and a small right kidney joined along the lower half of its medial border.

Fig. 37 Case 17.

Double Kidney.

Ascending pyelogram shows duplication of left ureter and pelvis. The upper segment is dilated.

Fig. 38 Case 17.

Double Kidney.

Arteriogram shows single blood supply to double left kidney. There is a double blood supply to the single right kidney.

Fig. 39 Case 17.

Double Kidney.

Nephrogram defines the elongated, enlarged double left kidney.

Fig. 40 Case 18.

Double Kidney.

Arteriogram shows normal blood supply to each kidney. The upper smaller segment of the right kidney is supplied by the upper smaller major division.

Fig. 41 Case 20.

Bilateral Duplication.

Excretion urogram shows duplication of pelvis and ureter of each side. The upper segments are smaller.

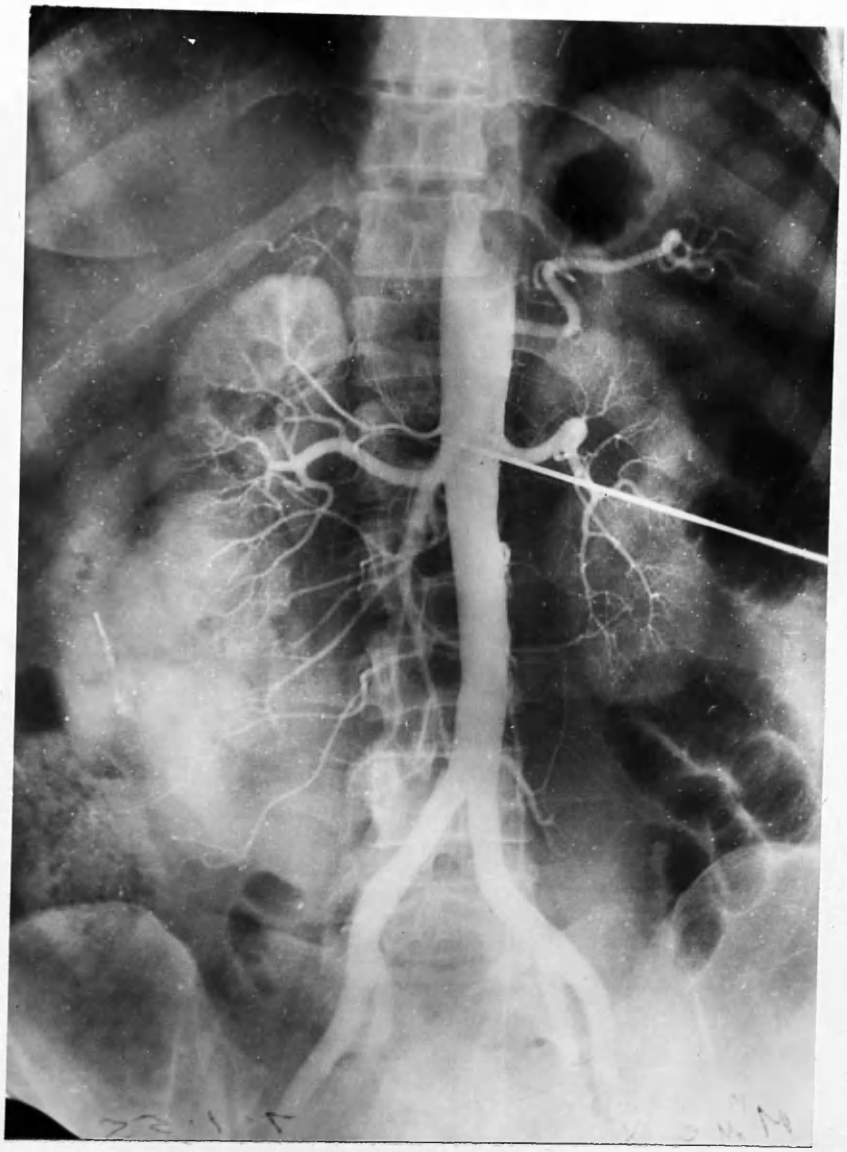

Fig. 42 Case 20.

Bilateral Duplication.

Arteriogram shows single left renal artery. There is a double blood supply to the right kidney, the small accessory vessel supplying the upper segment.

Fig. 43 Case 21.

Unilateral Fused Kidney.

Late arteriogram - early nephrogram phase shows double equal blood supply to fused, elongated left kidney. Air insufflation also used.

Fig. 44 Case 21.

Unilateral Fused Kidney.

Late excretion phase shows communication between small upper pelvis and lower malrotated one.

Fig. 45 Case 22.

Mobile Kidney.

Arteriogram shows normal site of origin but elongation of the vascular pedicle on the right side.

Fig. 46 Case 23.

Mobile Kidney.

Ascending pyelogram shows low-lying right kidney which is rotated on the transverse axis.

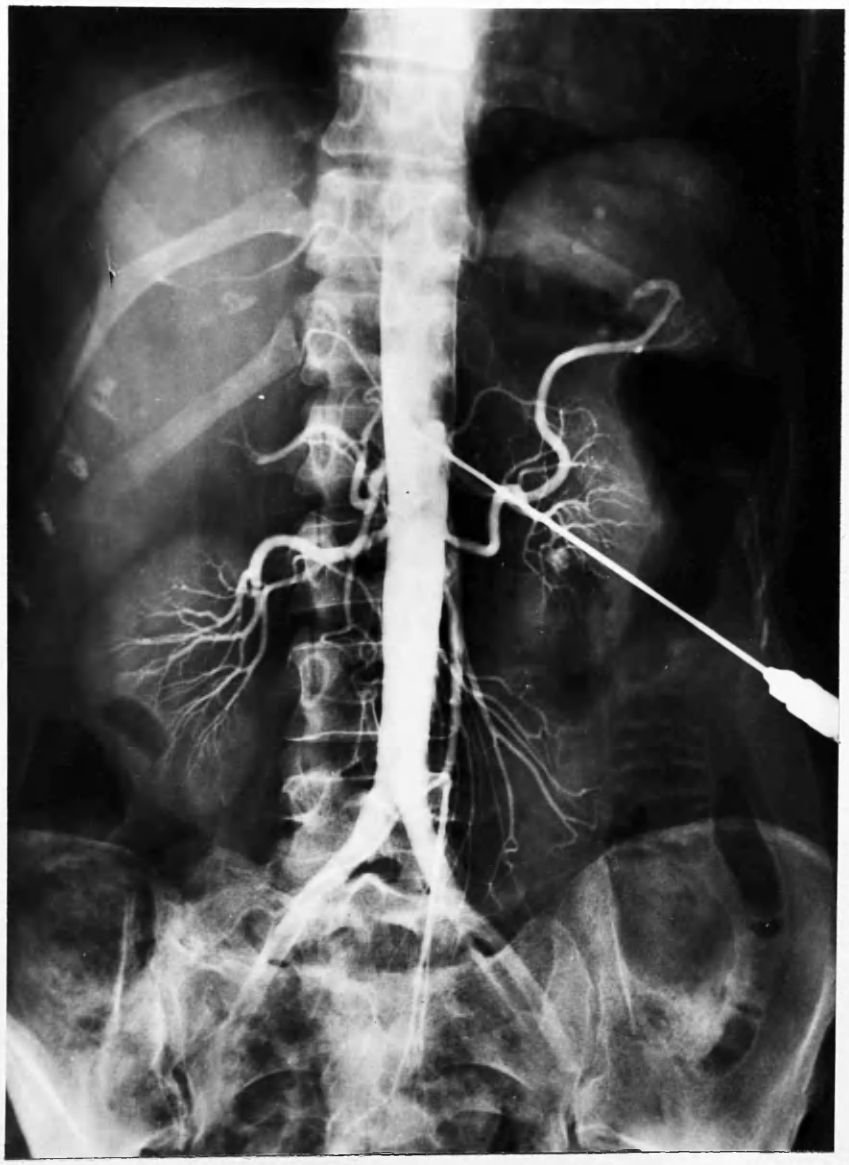

Fig. 47 Case 23.

Mobile Kidney.

Arteriogram shows normal site of origin of right renal artery with elongation and redundancy of vascular pedicle.

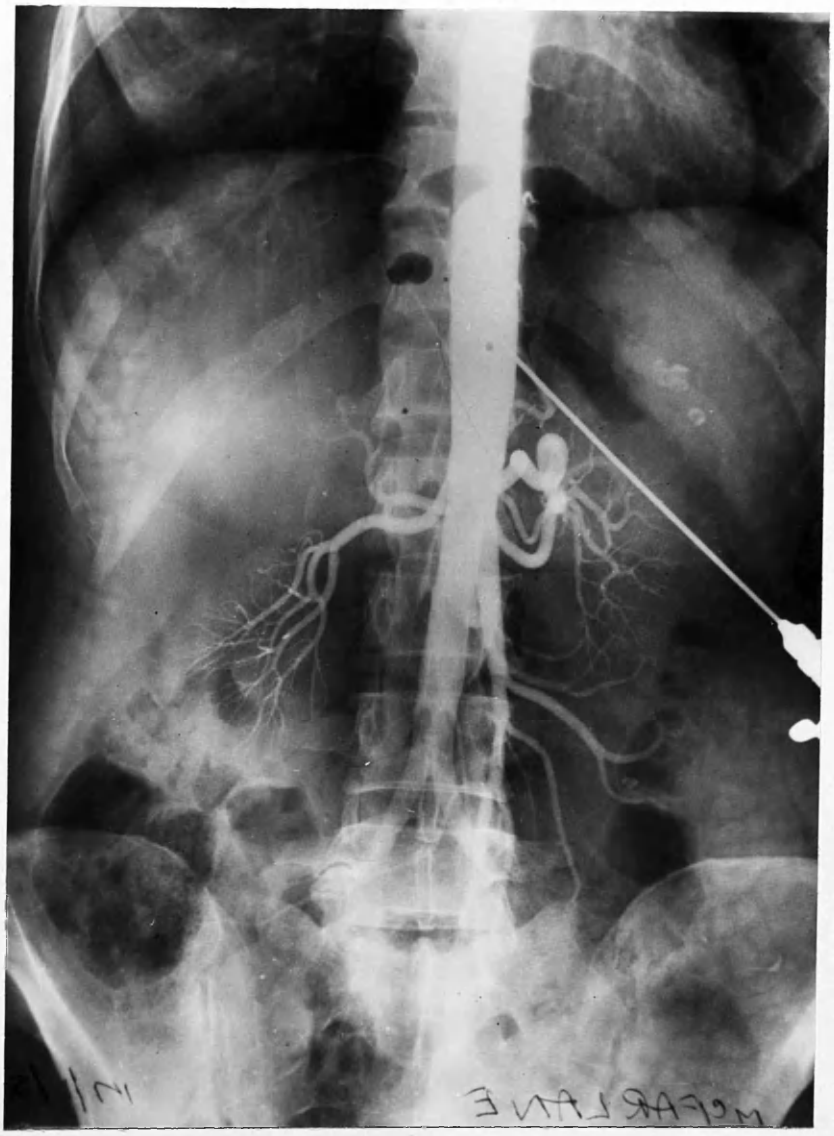

Fig. 48 Case 24.

Mobile Kidney.

Arteriogram shows normal level of origin of renal arteries with moderate elongation of right vascular pedicle.

Fig. 49 Case 24.

Mobile Kidney.

Nephrogram shows low-lying right kidney. Persistence of foetal polar approximation exaggerates the appearance of ptosis.

Fig. 50 Case 26.

Polycystic Kidney.

Arteriogram essentially normal. Relative deficiency of blood supply to lower pole of the left kidney.

Fig. 51 Case 27.

Polycystic Kidney.

Ascending pyelogram shows bizarre appearance of left kidney with smooth indentation of lower medial calyx. Previous operation performed on this kidney.

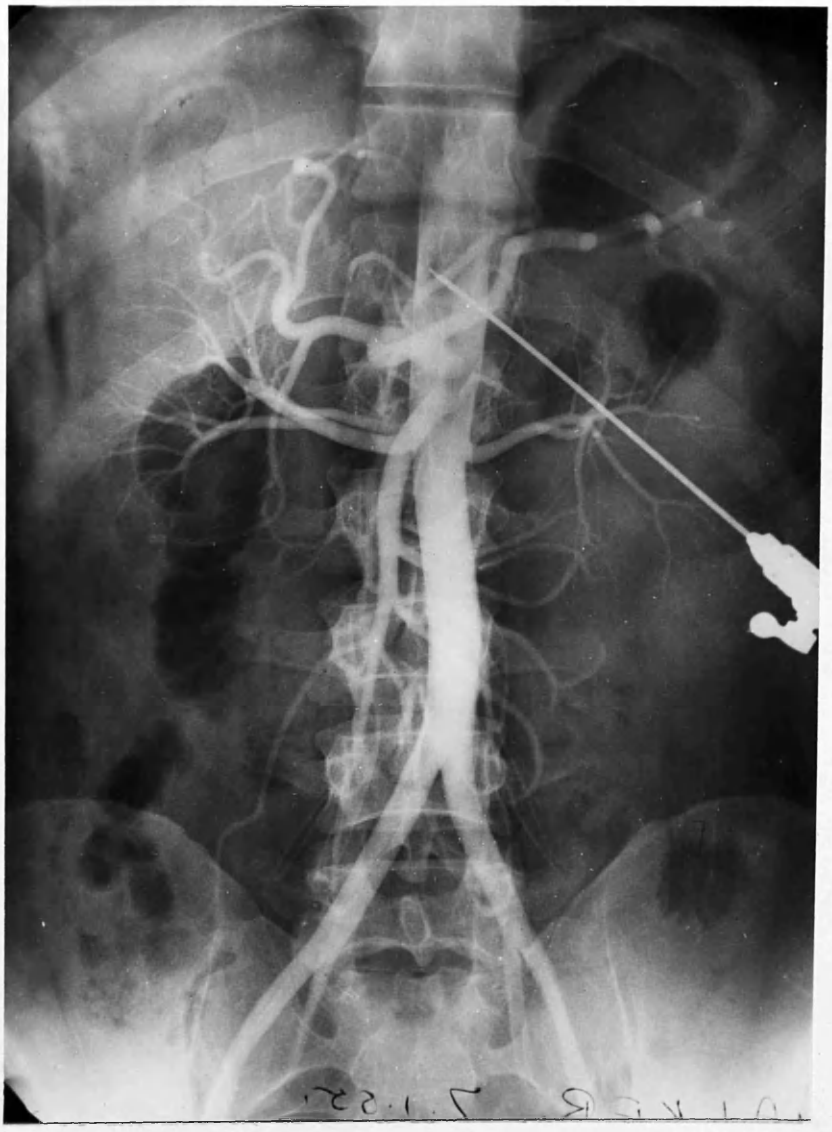

Fig. 52 Case 27.

Polycystic Kidney.

Arteriogram shows thinning and displacement of the major branches of the left kidney. Regular displacement to some degree of the interlobar vessels of right upper pole.

Fig. 53 Case 28.

Polycystic Kidney.

Arteriogram shows gross displacement and compression of all divisions and branches of both renal arteries.

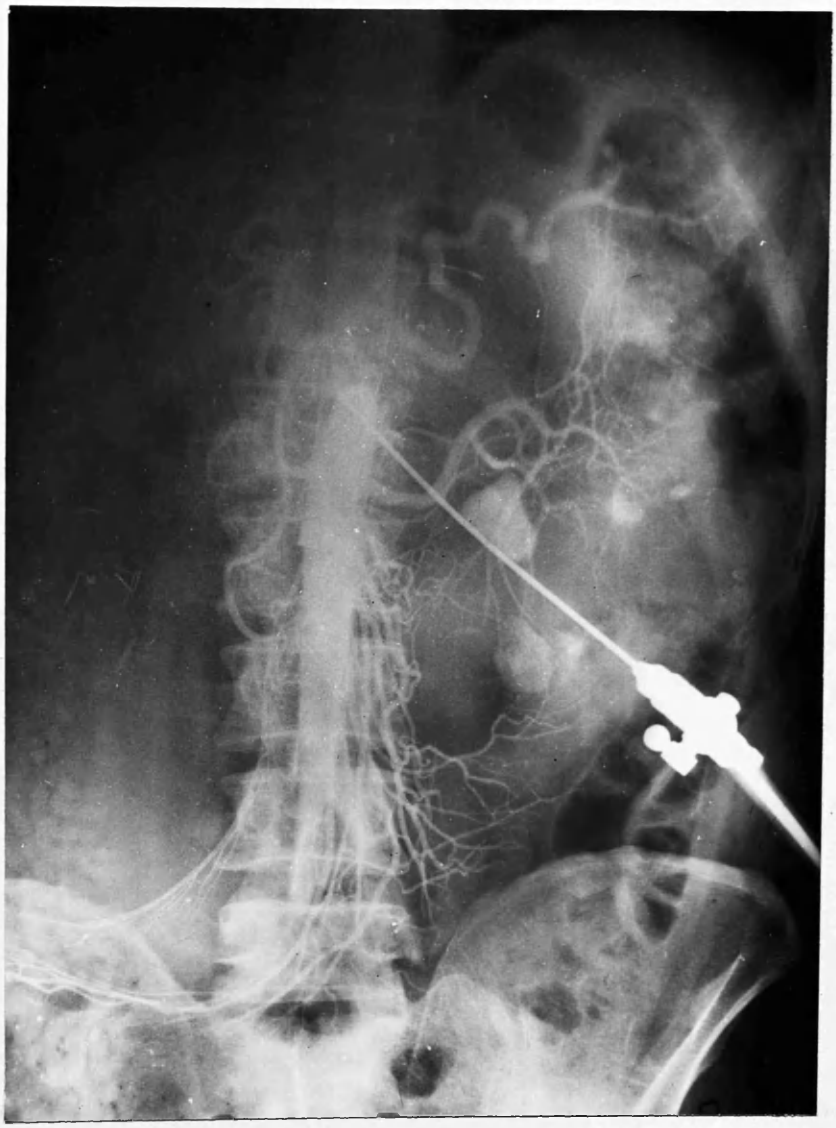

Fig. 54 Case 29.

Polycystic Kidney.

Arteriogram shows gross vascular deficiency to right kidney. Stones present in left kidney with poor blood supply at lower pole. Two terminal branches are displaced in a regular arc.

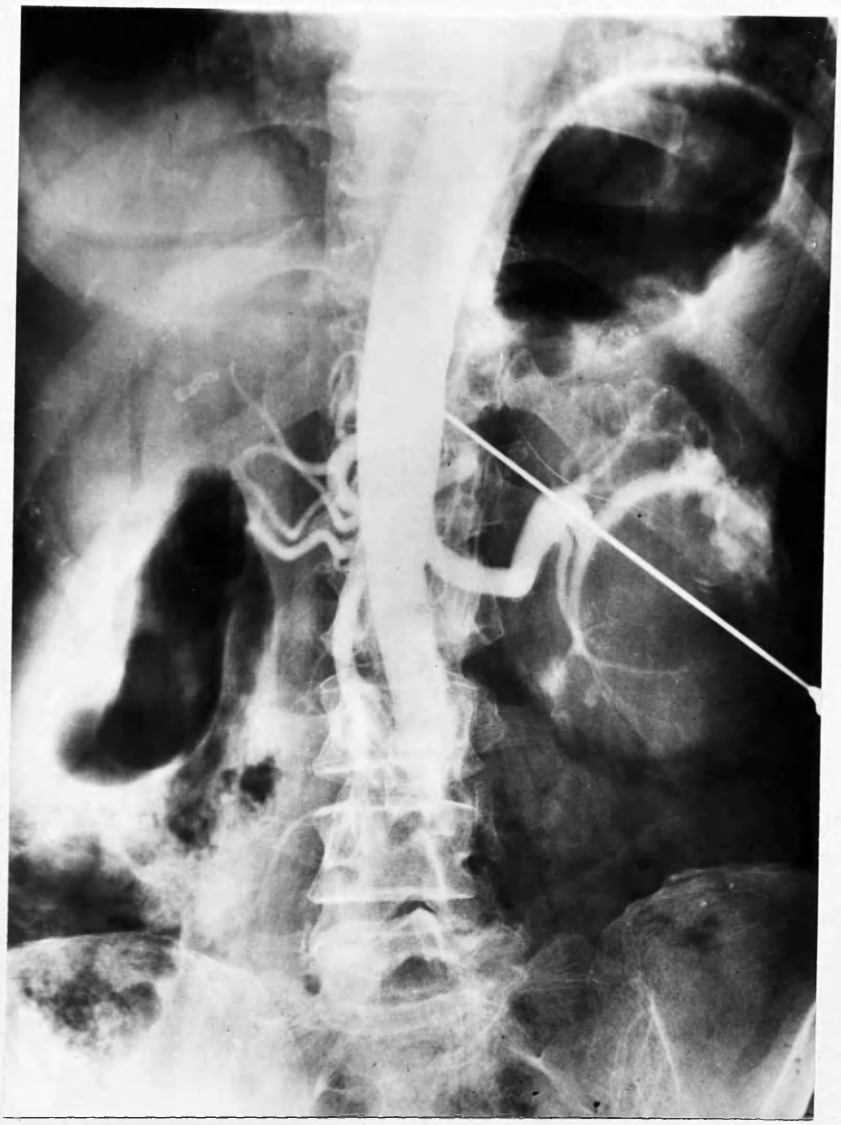

Fig. 55 Case 30.

Renal Adeno-carcinoma.

Arteriogram shows hypertrophy of left renal artery and its main divisions. The latter are displaced and pooling of dye is marked.

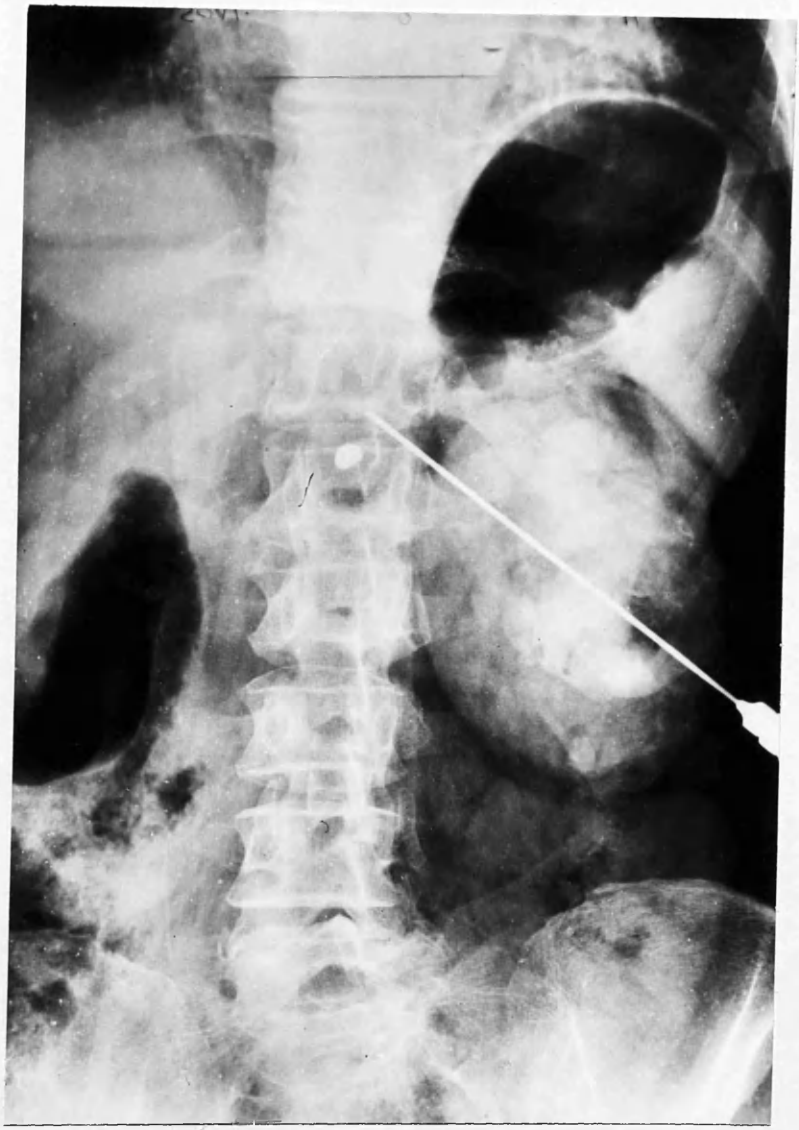

Fig. 56 Case 30.

Renal Adeno-carcinoma.

Nephrogram shows mass of tumour and more extensive pooling of dye.

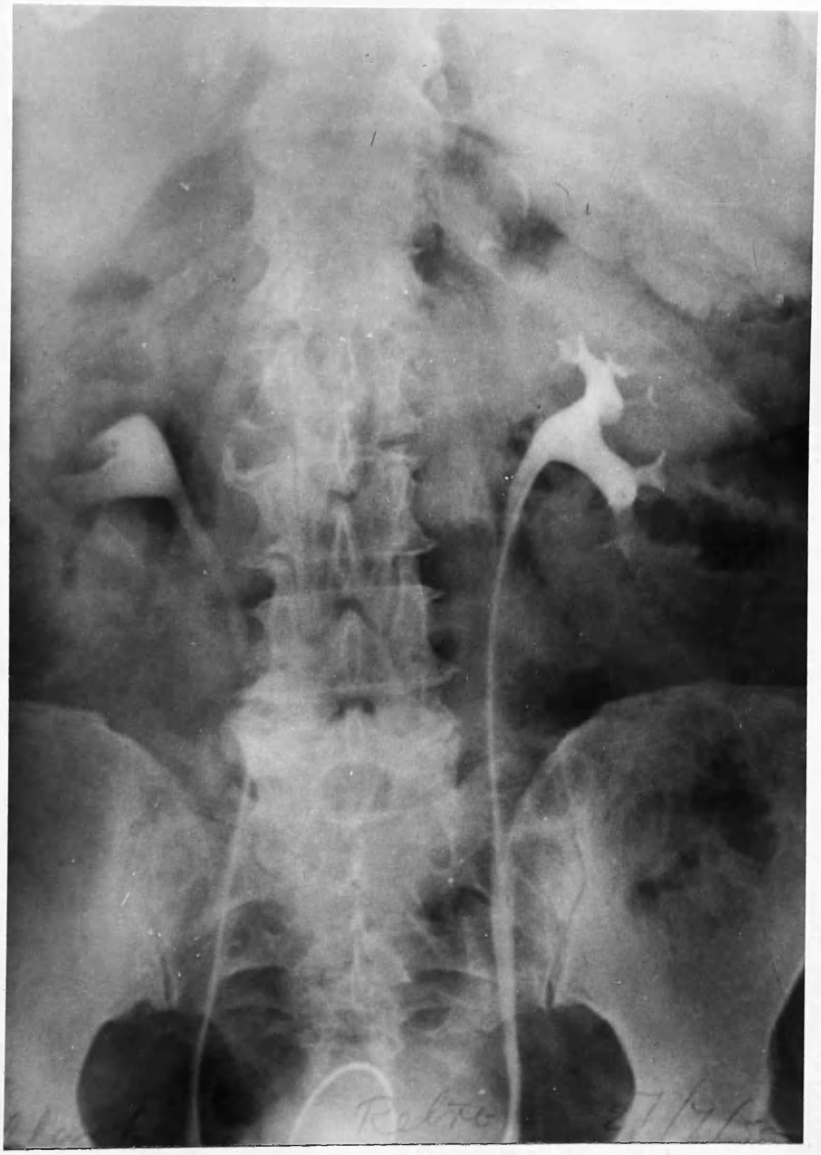

Fig. 57 Case 31.

Renal Adeno-carcinoma.

Ascending pyelogram shows incomplete delineation of the upper major calyx group on the right side. This is suggestive but not absolutely diagnostic of neoplasm.

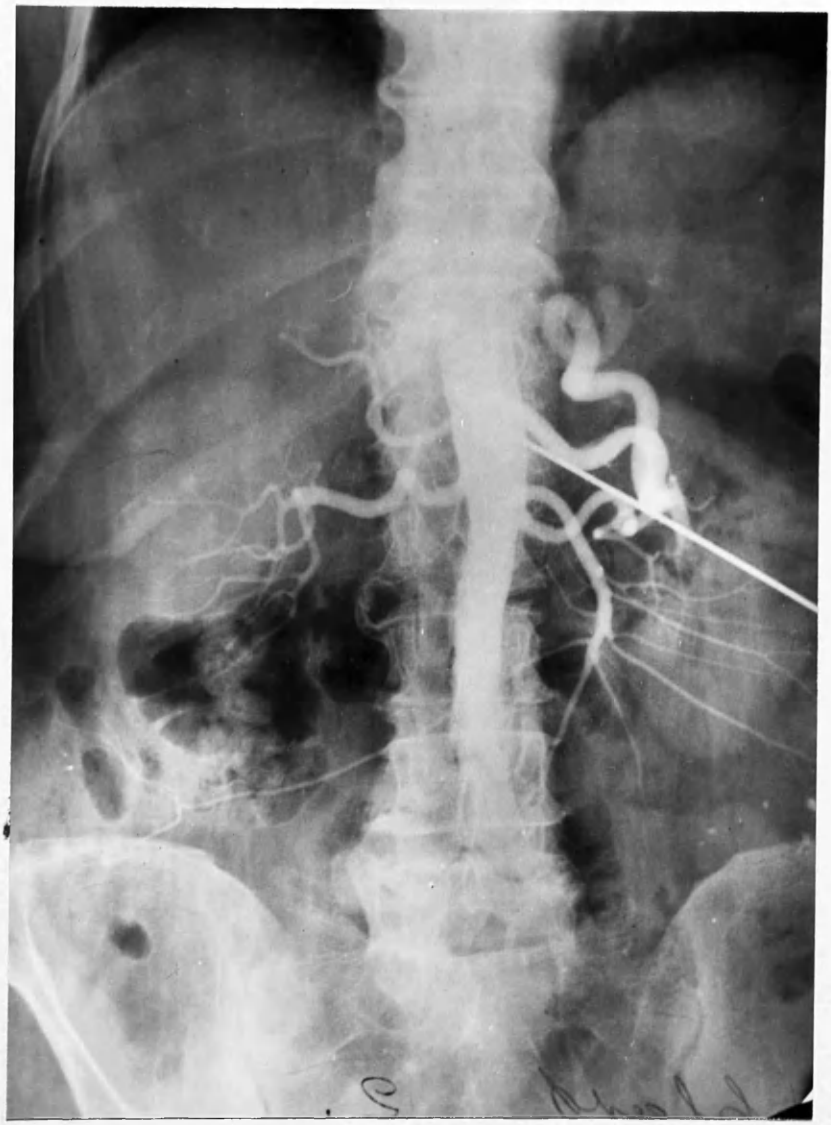

Fig. 58 Case 31.

Renal Adeno-carcinoma.

Arteriogram shows slight hypertrophy of right renal artery. A faint irregular area of dye pooling is evident on each side of the terminal branch of the upper division. The upper pole is broadened and enlarged.

Fig. 59 Case 32.

Renal Adeno-carcinoma.

Late arteriogram - early nephrogram phase shows enlarged right kidney with irregular pooling in lower and middle parts of kidney.

Fig. 60 Case 33.

Renal Adeno-carcinoma.

Nephrogram and air insufflation define right renal enlargement. There is no fixation and pooling is not marked being present in a small area overlying the 12th rib.

Fig. 61 Case 34.

Renal Adeno-carcinoma.

Ascending pyelogram shows distraction of calyceal pattern the lower calyx being broadened and elongated.

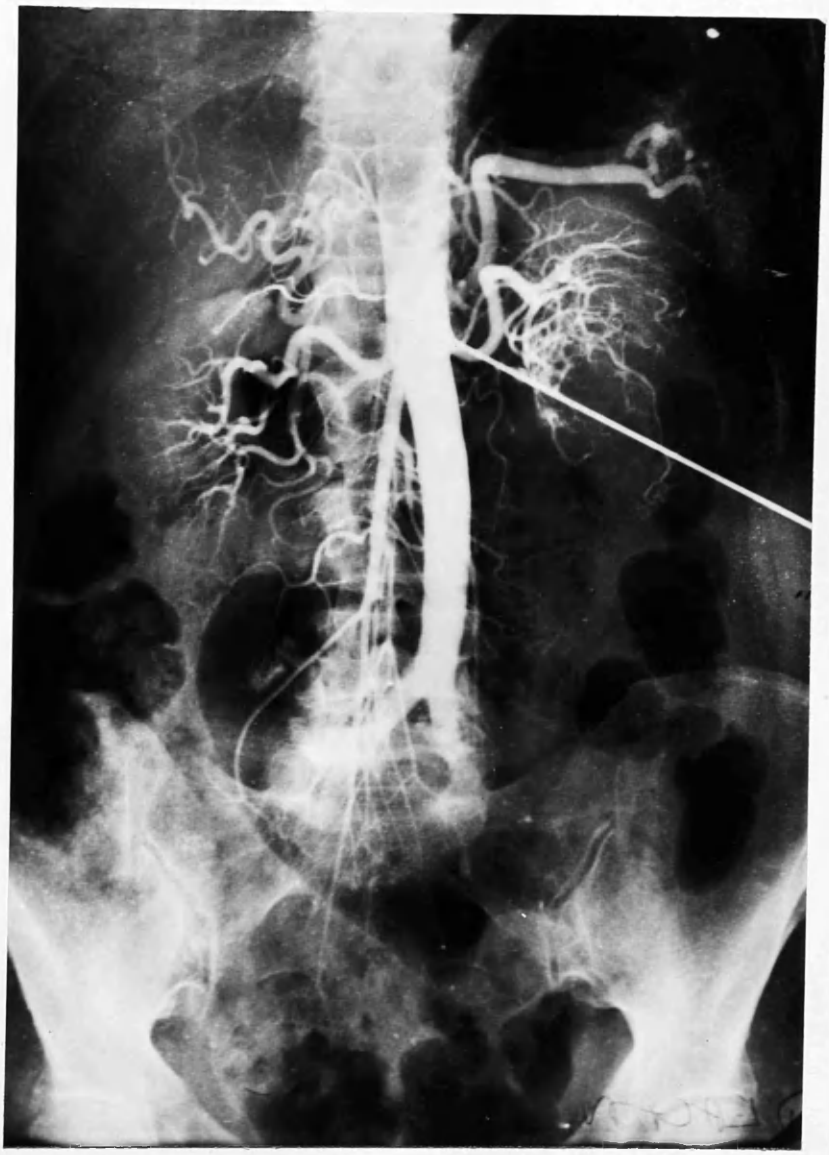

Fig. 62 Case 34.

Renal Adeno-carcinoma.

Arteriogram shows increased vascularity in region of left renal hilum with vascular deficiency towards lower pole.

Fig. 63 Case 34.

Renal Adeno-carcinoma.

Nephrogram shows irregular dense parenchymal shadow occupying middle and lower parts of kidney. Note normal renal "cap".

Fig. 64 Case 35.

Renal Adeno-carcinoma.

Ascending pyelograms show deformity of upper group of calyces of the left kidney.

Fig. 65 Case 35.

Renal Adeno-carcinoma.

Nephrogram shows well-demarcated round dense shadow towards lower half of left kidney.

Fig. 66 Case 36.

Renal Adeno-carcinoma.

Ascending pyelogram shows dilatation of right renal pelvis with "cut-off" appearance at uretero-pelvic junction.

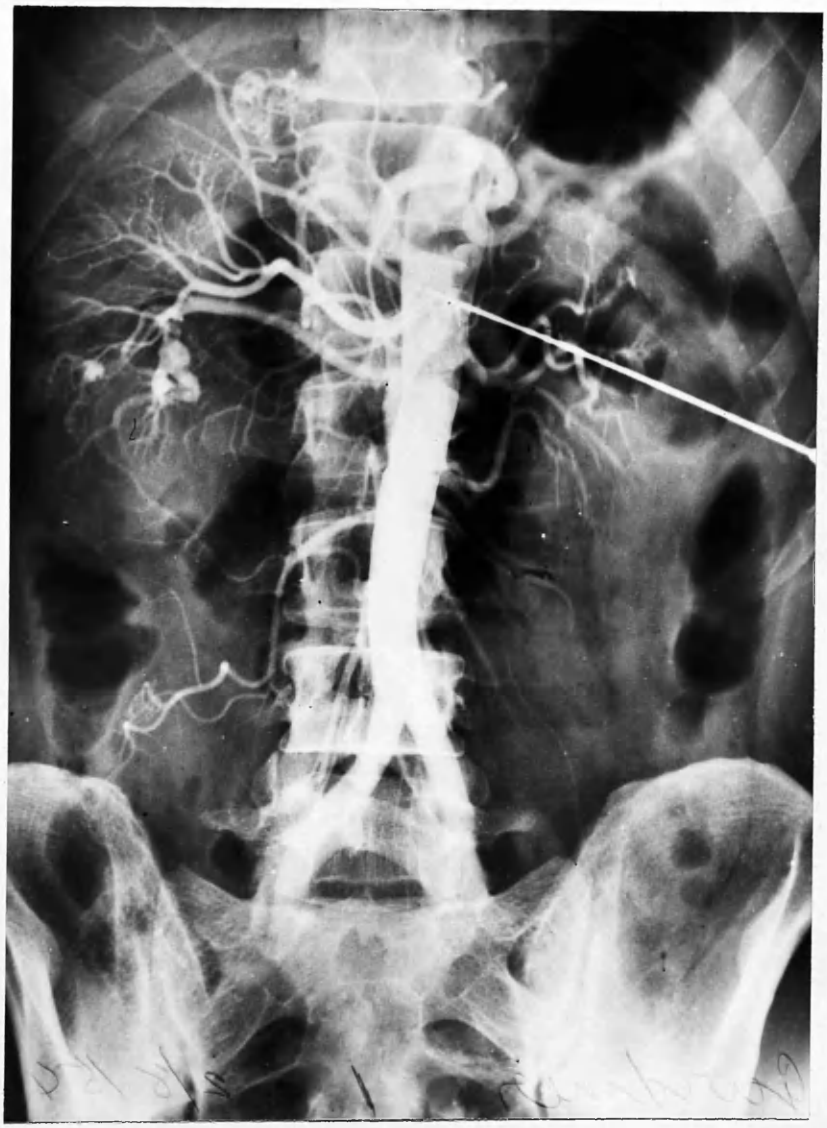

Fig. 67 Case 36.

Renal Adeno-carcinoma.

Arteriogram shows double blood supply to each kidney. Two areas of dense pooling in lower half of right kidney. Note blood supply to right adrenal gland.

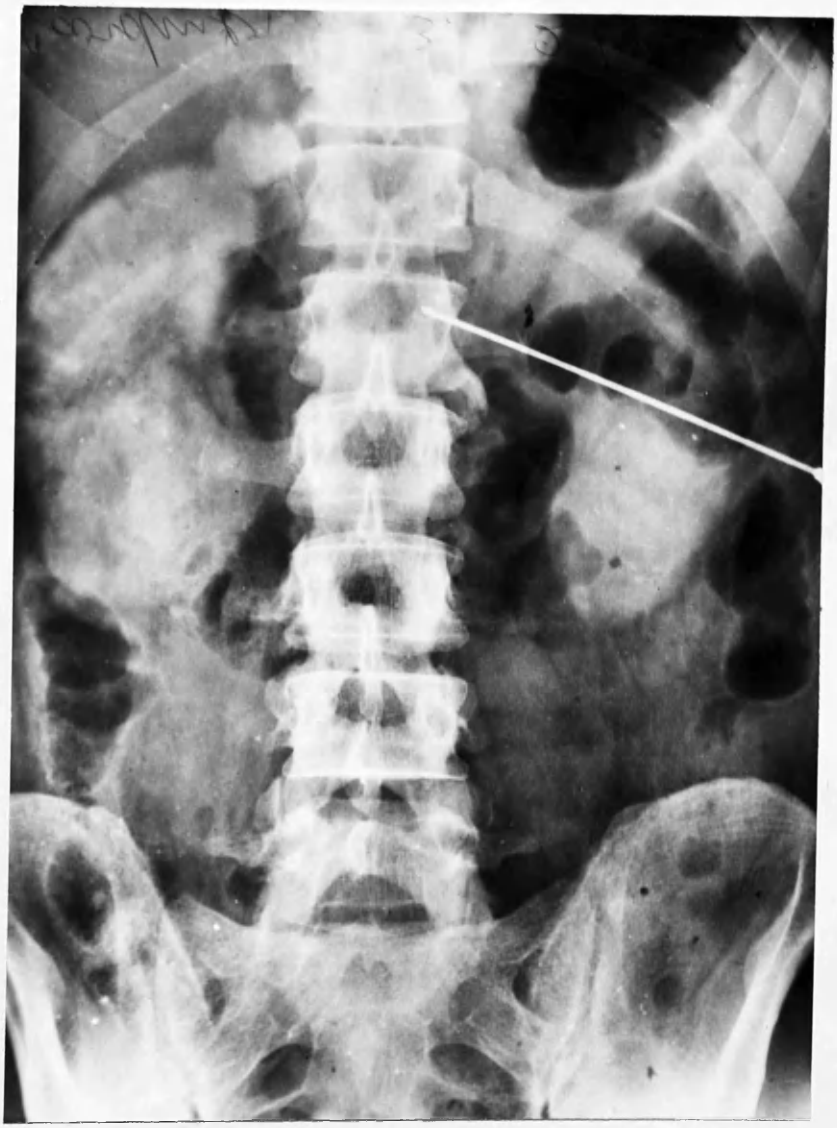

Fig. 68 Case 36.

Renal Adeno-carcinoma.

Nephrogram shows broadening of right lower pole due to tumour. Note right "adrenogram".

Fig. 69 Case 37.

Renal Adeno-carcinoma.

Arteriogram shows vascular condensation in upper part of left renal hilum.

Fig. 70 Case 37.

Renal Adeno-carcinoma.

Nephrogram shows indeterminate area of dye concentration in upper medial part of left kidney.

Fig. 71 Case 38.

Renal Fibrosarcoma.

Arteriogram shows displacement of right renal artery. Terminal branches are lengthened and contain small collections of dye. Note extravasation from first puncture.

Fig. 72 Case 39.

Renal Adenoma.

Arteriogram shows hypertrophy of right renal artery and its divisions which are displaced.

Fig. 73 Case 39.

Renal Adenoma.

Nephrogram shows tumour mass in right kidney. Faint pooling around the periphery.

Fig. 74 Case 40.

Squamous Carcinoma of Renal Pelvis.

Arteriogram shows obliterative endarteritis of left renal artery due to hydronephrosis.

Fig. 75 Case 40.

Squamous Carcinoma of Renal Pelvis.

Nephrogram shows faint outline of enlarged hydronephrotic left kidney.

Fig. 76 Case 42.

Ureteric Carcinoma.

Arteriogram shows small right renal artery with displacement of divisions.

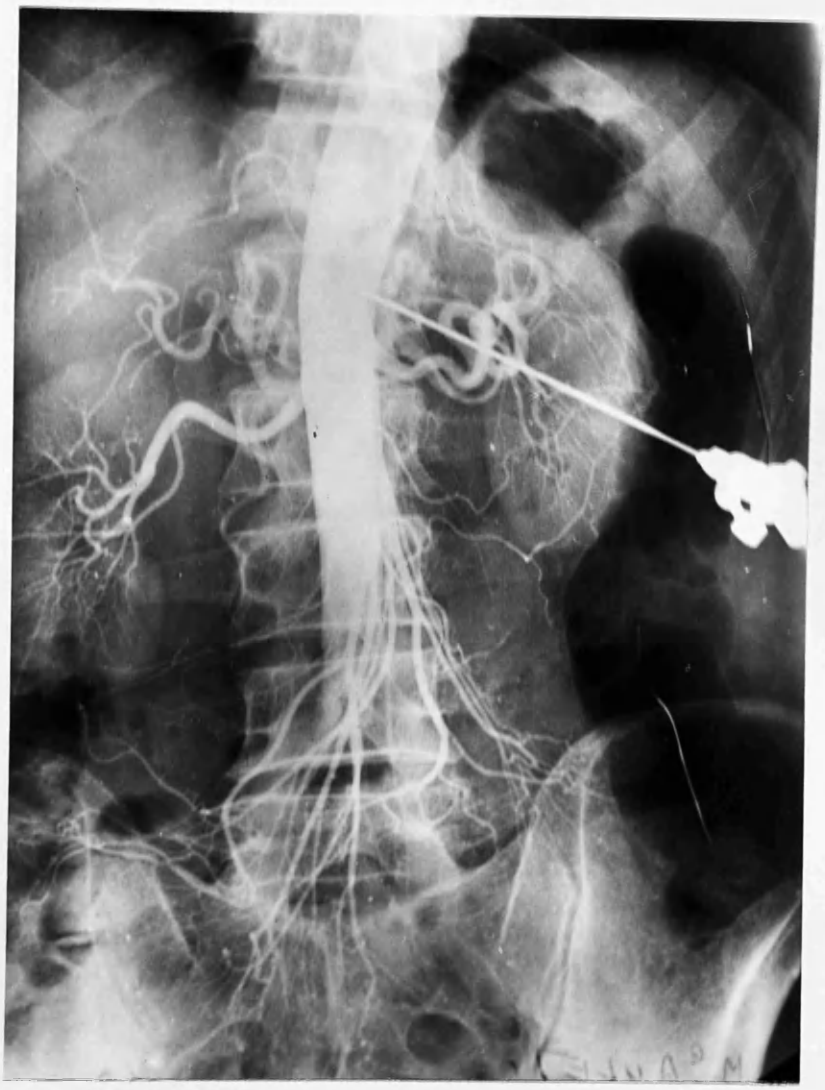

Fig. 77 Case 44.

Suspected Renal Tumour.

Arteriogram shows normal bilateral renal blood supply.

Fig. 78 Case 45.

Suspected renal Tumour.

Ascending pyelogram shows dilatation of right upper calyx with elongation of the neck. Right middle calyx appears compressed.

Fig. 79 Case 45.

Suspected Renal Tumour.

Arteriogram shows fairly normal vascularity of right kidney with no pooling of dye. Note tortuous splenic artery.

Fig. 80 Case 46.

Unilateral Renal Bleeding.

Arteriogram shows normal blood supply to each kidney with normal intrarenal pattern. The right renal artery is elongated due to some degree of ptosis.

Fig. 81 Case 48.

Unilateral Renal Bleeding.

Arteriogram shows double blood supply to each kidney but with no pooling of dye.

Fig. 82 Case 49.

Unilateral Renal Bleeding.

Excretion urogram shows attenuated neck of left upper calyx with "cut-off" at uretero-pelvic junction.

Fig. 83 Case 49.

Unilateral Renal Bleeding.

Arteriogram shows normal bilateral renal blood supply with no evidence of pooling.

Fig. 84 Case 52.

Unilateral Renal Bleeding.

Arteriogram shows some reduction in blood supply to left kidney but no evidence of pooling.

Fig. 85 Case 53.

Hydronephrosis.

Excretion urogram shows moderate dilatation of the pelvis and calyces of the right kidney.

Fig. 86 Case 53.

Hydronephrosis.

Ascending pyelogram shows fullness of right renal pelvis and slight dilatation of the calyces.

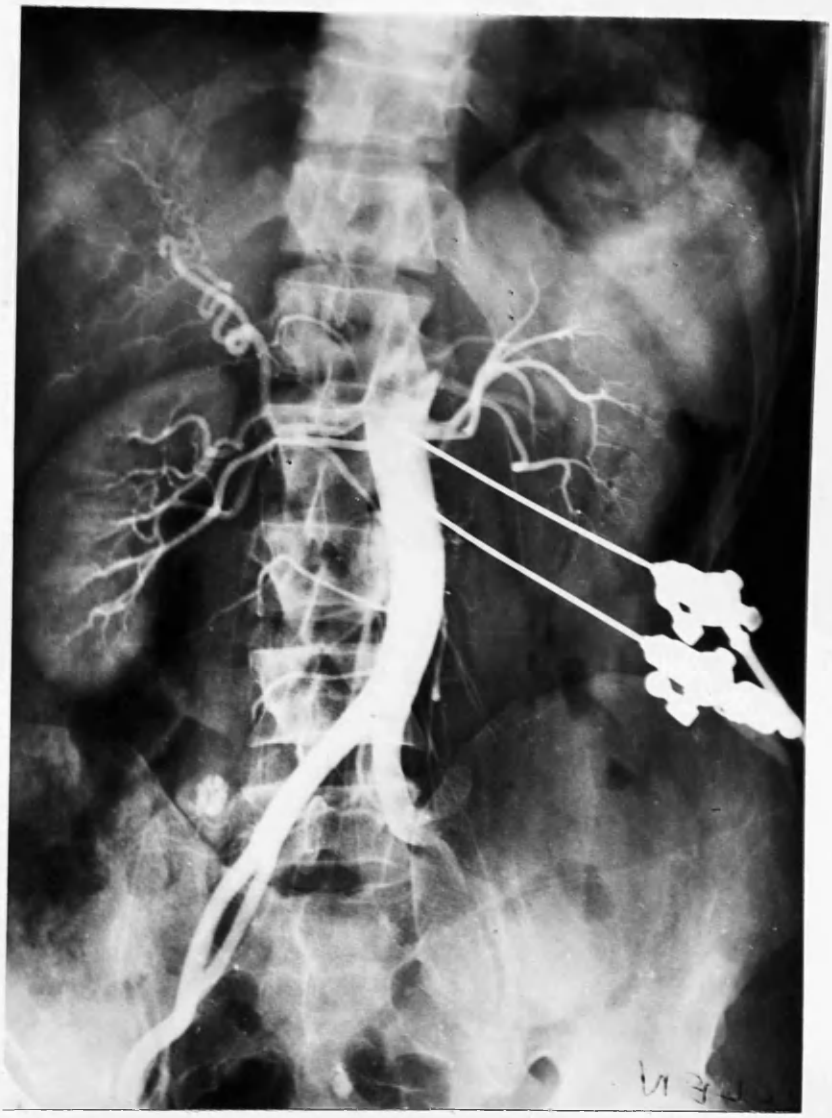

Fig. 87 Case 53.

Hydronephrosis.

Arteriogram shows double blood supply to both kidneys. The hydronephrotic right kidney has a good parenchymal supply and the accessory artery is not an obstructive factor.

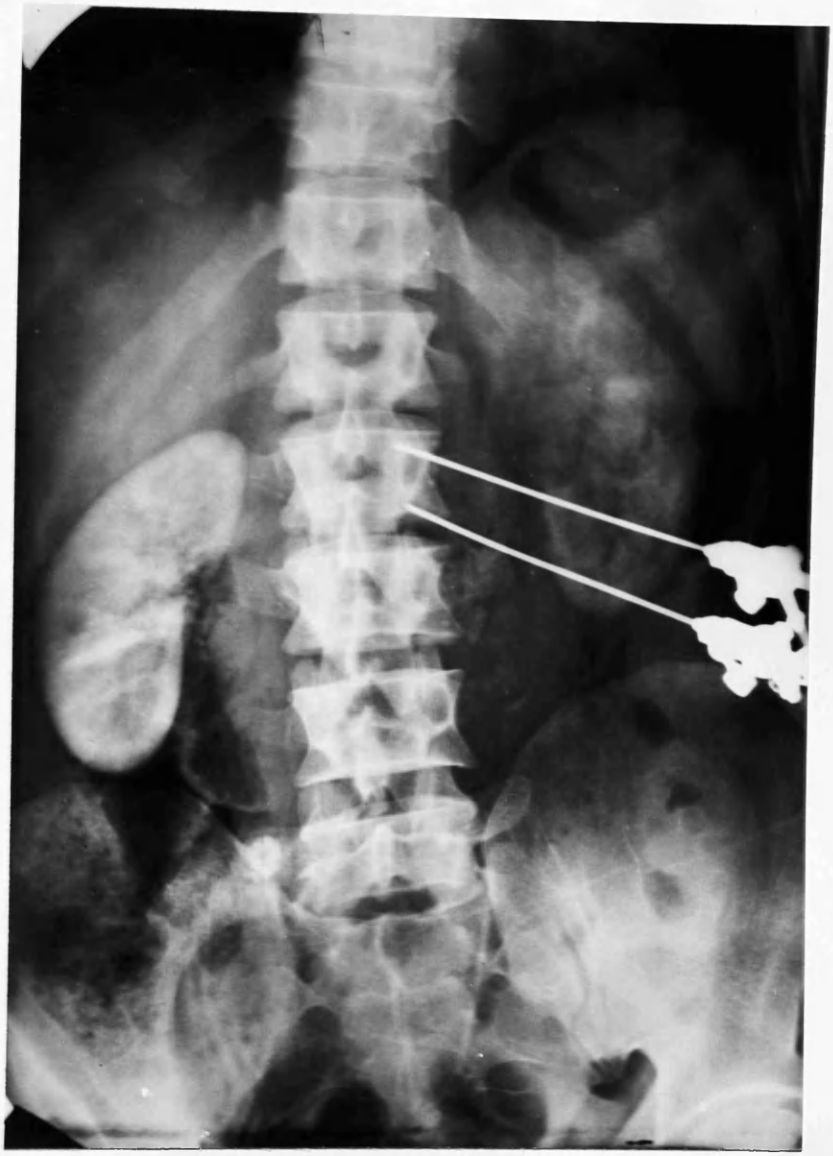

Fig. 88 Case 53.

Hydronephrosis.

Nephrogram shows normal outline and parenchymal density of the right kidney.

Fig. 89 Case 53.

Hydronephrosis.

Excretion urogram shows reduction of dilatation after Pituitrin therapy.

Fig. 90 Case 54.

Hydronephrosis.

Combined arteriogram and ascending pyelogram show no hydronephrosis and good blood supply to left kidney. Accessory vessel to lower pole crosses below ureteropelvic junction. Note stump of right renal artery.

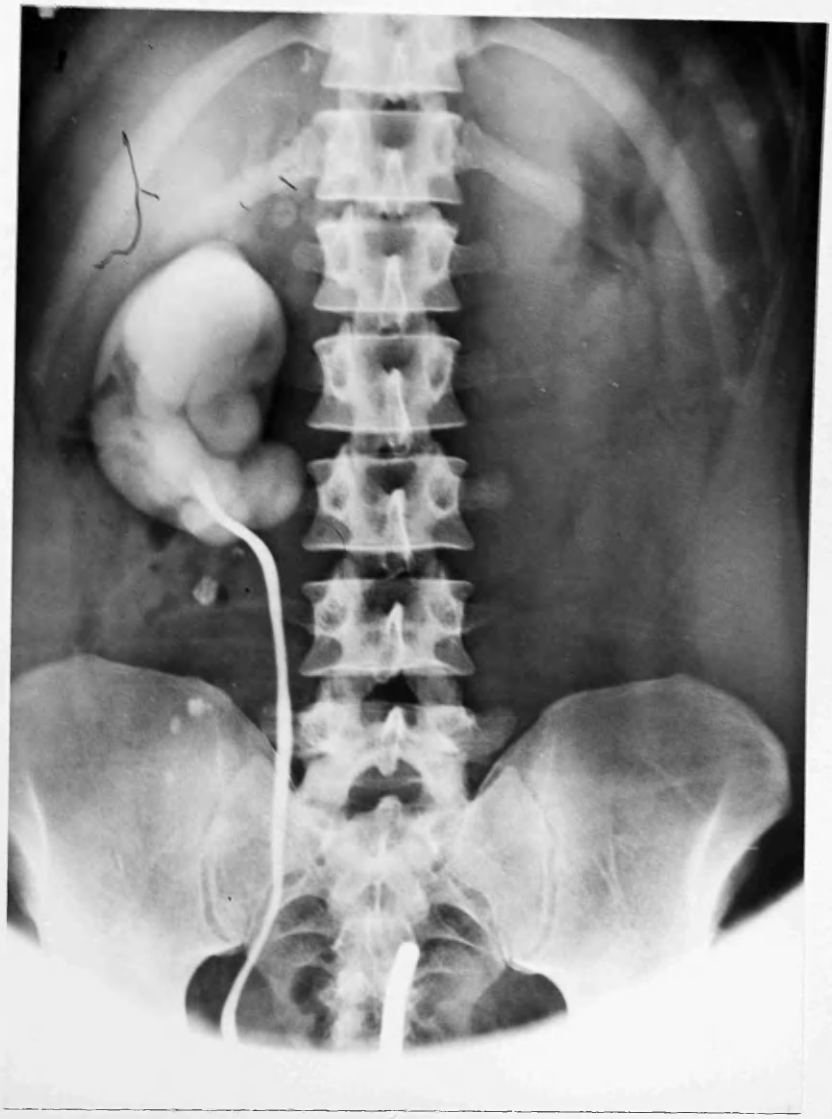

Fig. 91 Case 57.

Hydronephrosis.

Ascending pyelogram shows marked hydronephrosis of the right kidney.

Fig. 92 Case 57.

Hydronephrosis.

Arteriogram shows small right renal artery whose main divisions are thinned, displaced and lengthened.

Fig. 93 Case 58.

Hydronephrosis.

Nephrogram shows right kidney to be enlarged, elongated and of poor parenchymal density.

Fig. 94 Case 61.

Hydronephrosis.

Arteriogram shows vascular deficiency to left kidney. The renal artery is small with no cortical branching. Note athero-sclerotic stenosis near its origin.

Fig. 95 Case 62.

Hydronephrosis.

Ascending pyelogram shows marked dilatation of right renal pelvis and calyces. There is stenosis at the uretero-pelvic junction.

Fig. 96 Case 62

Hydronephrosis.

Arteriogram shows reduction in right renal vasculature but still adequate for satisfactory function.

Fig. 97 Case 62.

Hydronephrosis.

Nephrogram shows no enlargement of renal substance with satisfactory parenchymal density.

Fig. 98 Case 62.

Hydronephrosis.

Post-operative excretion urogram shows good concentration with reduction in calyceal dilatation.

Fig. 99 Case 63.

Hydronephrosis.

Excretion urogram shows dilatation of right renal pelvis and calyces.

Fig. 100 Case 63.

Hydronephrosis.

Arteriogram shows reduced vascularity to right kidney but interlobar vessels still adequate. Note accessory artery to lower pole of left kidney and hepatic artery arising from superior mesenteric.

Fig. 101 Case 63.

Hydronephrosis.

Post-operative excretion urogram shows good concentration with little dilatation of calyces.

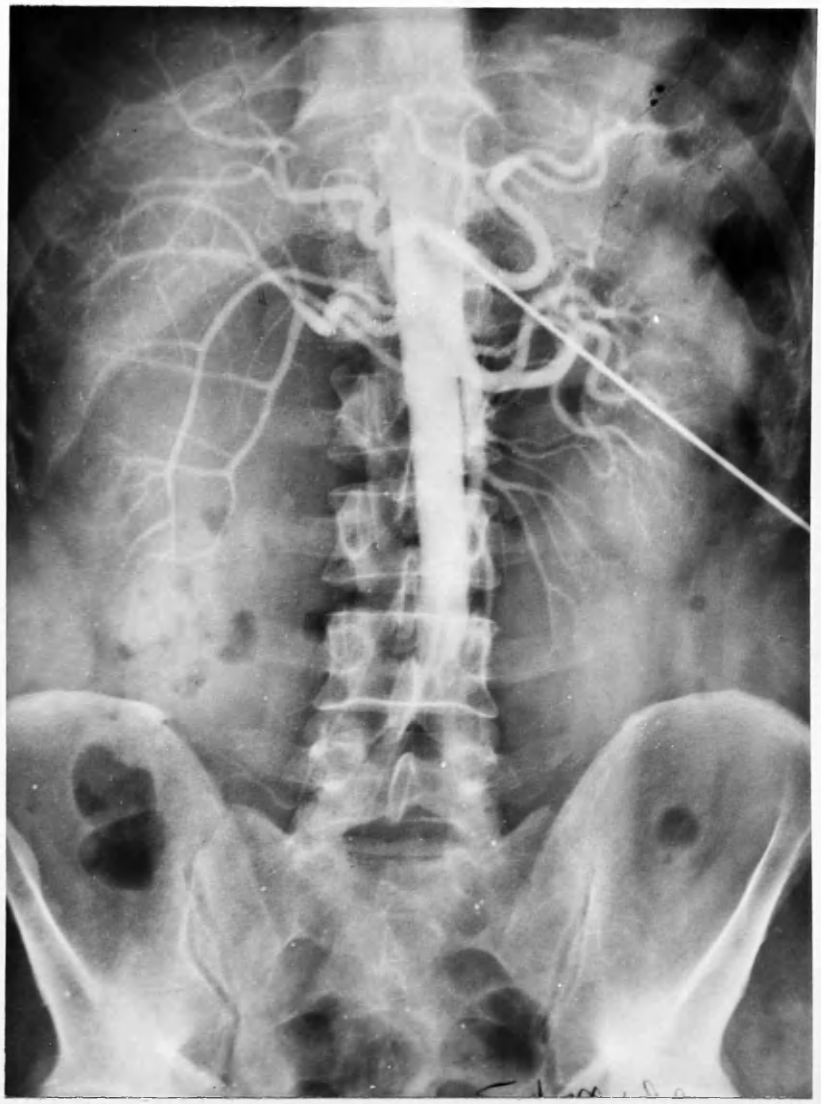

Fig. 102 Case 64.

Hydronephrosis.

Arteriogram shows double blood supply to each kidney. Note how accessory vessel to right upper pole arises from the aorta below the main vessel. Main blood supply to affected right kidney still adequate.

Fig. 103 Case 64.

Hydronephrosis.

Nephrogram shows enlargement and elongation of right kidney but parenchymal density just adequate for preservation.

Fig. 104 Case 65.

Hydronephrosis.

Right ascending pyelogram shows large triangular area of dye in renal pelvis. No calyceal detail or parenchymal outline defined.

Fig. 105 Case 65.

Hydronephrosis.

Arteriogram shows a good blood supply to both kidneys. Cortical arborisation still present on right side.

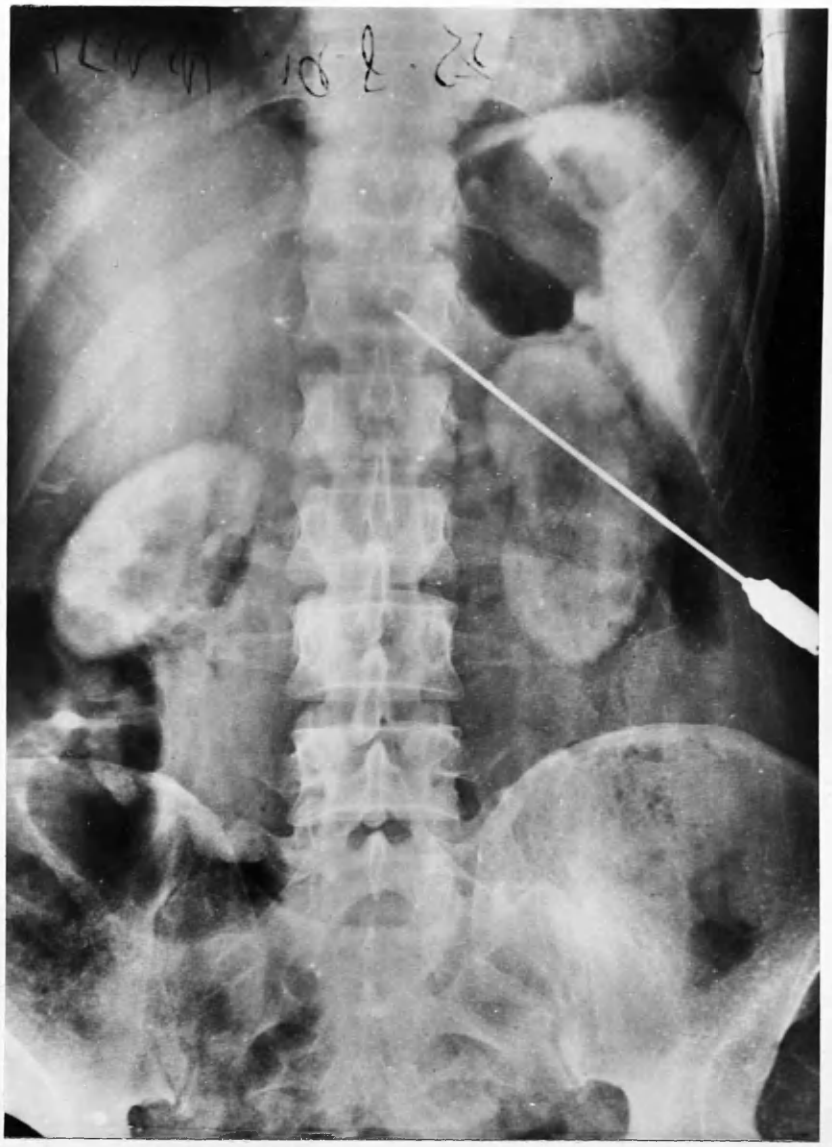

Fig. 106 Case 65.

Hydronephrosis.

Nephrogram shows good parenchymal density of affected right kidney which is displaced by the enlarged renal pelvis.

Fig. 107 Case 66.

Hydronephrosis.

Left ascending pyelogram shows uretero-pelvic obstruction and faint shadow of renal dilatation.

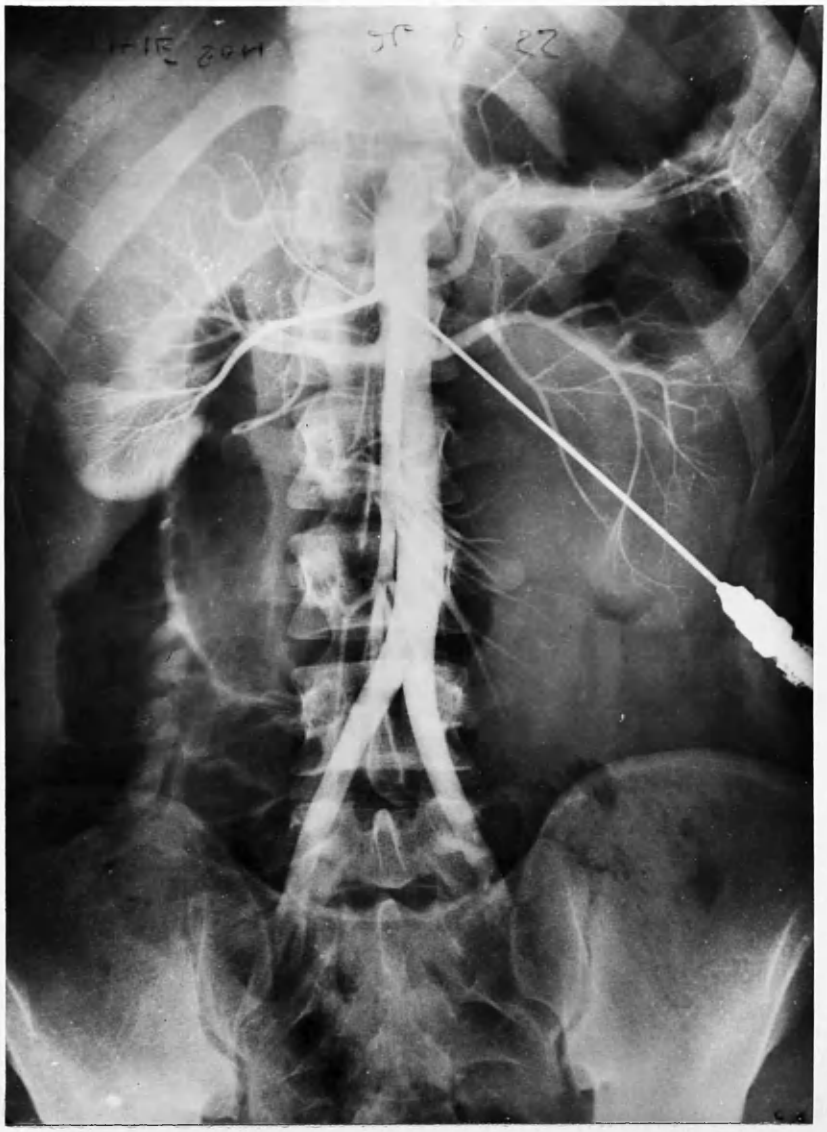

Fig. 108 Case 66.

Hydronephrosis.

Arteriogram shows typical appearances of hydronephrosis. Major divisions and branches lengthened and displaced with reduction in cortical arborisation. Note accessory lower polar artery to right kidney arises above main vessel.

Fig. 109 Case 66.

Hydronephrosis.

Nephrogram shows reduction in parenchymal density of the left kidney.

Fig. 110 Case 67.

Hydronephrosis.

Ascending pyelogram shows moderate dilatation of right renal pelvis and calyces. Appearance of "cut-off" at uretero-pelvic junction.

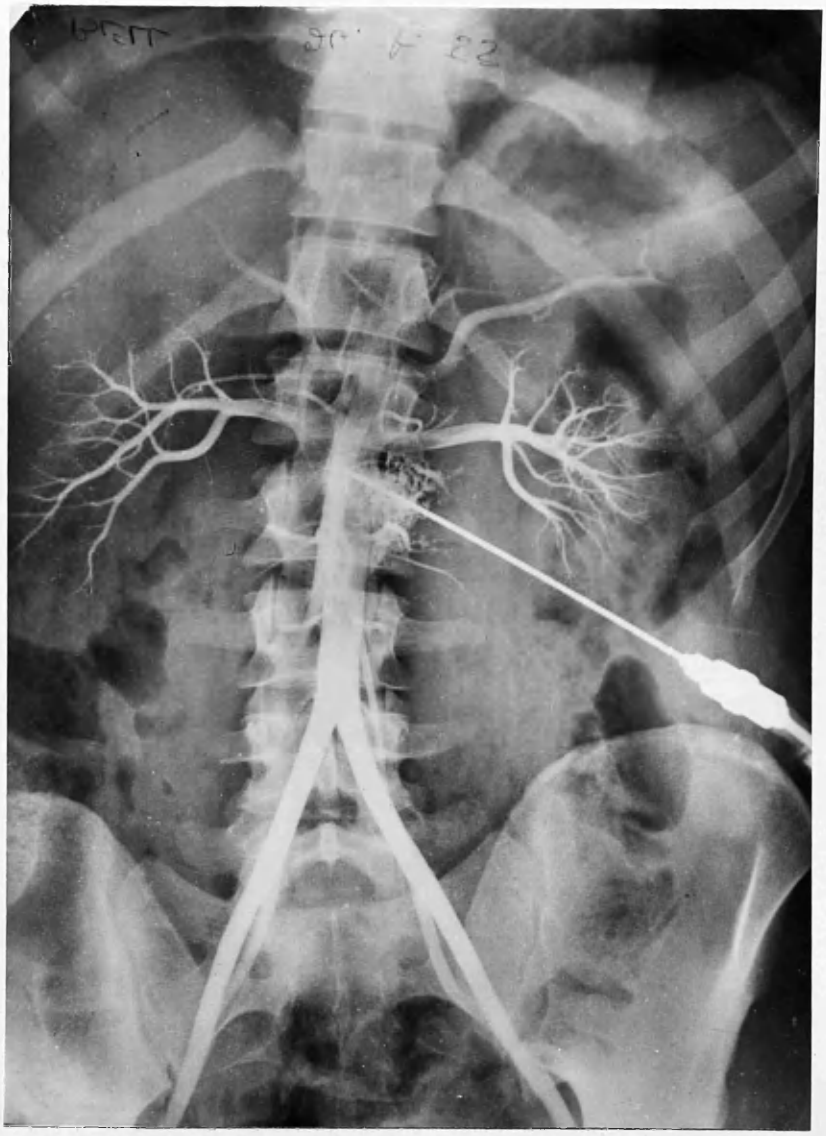

Fig. 111 Case 67.

Hydronephrosis.

Arteriogram shows good blood supply to right kidney although cortical arborisation is reduced.

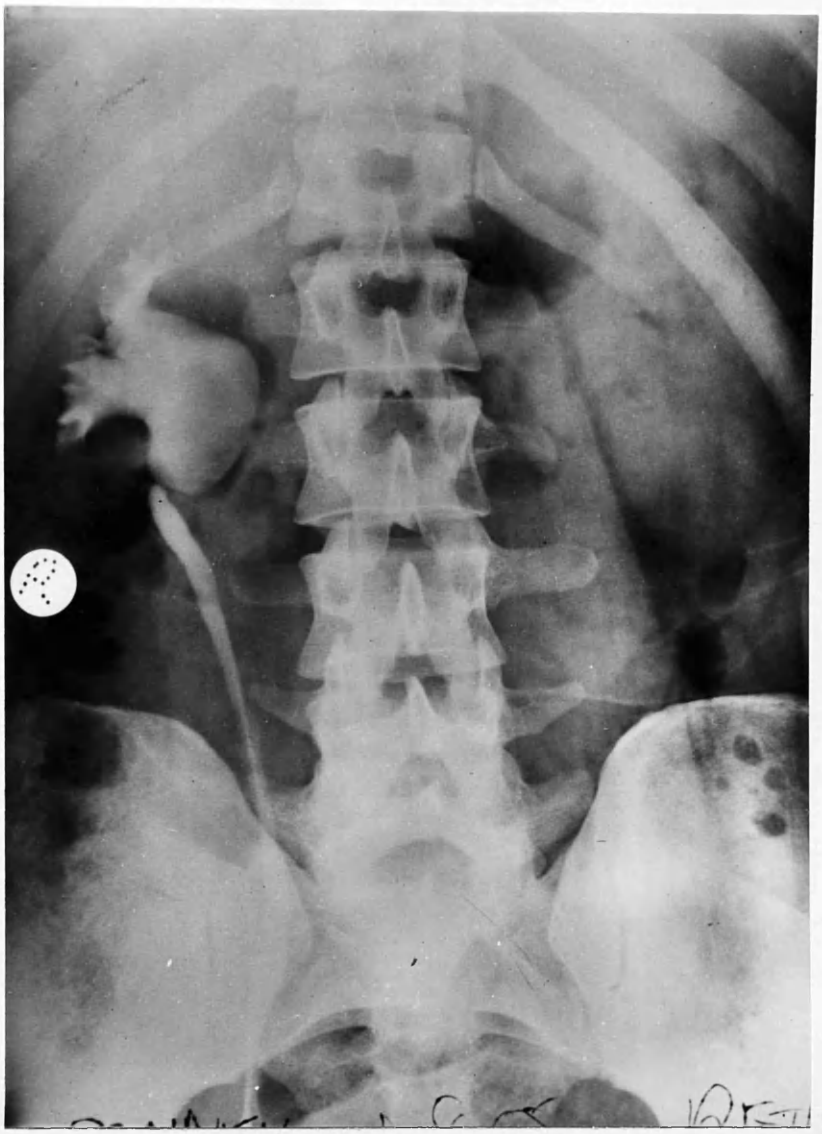

Fig. 112 Case 68.

Hydronephrosis.

Ascending pyelogram shows pelvic dilatation with "cut-off" at uretero-pelvic junction.

Fig. 113 Case 68.

Hydronephrosis.

Arteriogram shows good vasculature to affected right kidney. No artery is responsible for uretero-pelvic obstruction.

Fig. 114 Case 69.

Hydronephrosis.

Ascending pyelogram shows dilatation of left renal pelvis and appearance of "cut-off" at uretero-pelvic junction.

Fig. 115 Case 69.

Hydronephrosis.

Arteriogram shows good double blood supply to affected left kidney. Large accessory vessel to lower pole is a factor in obstruction.

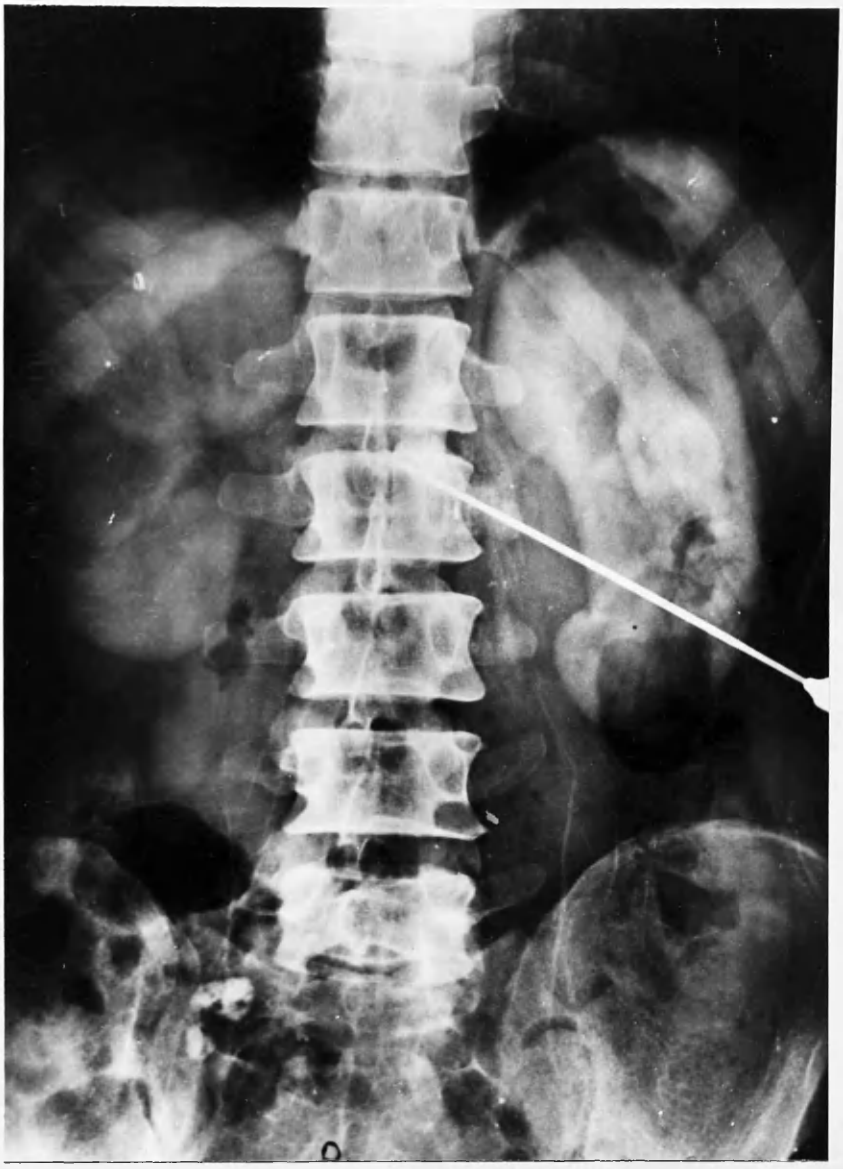

Fig. 116 Case 69.

Hydronephrosis.

Nephrogram shows enlarged left kidney with hilar depression. Total parenchymal density is good.

Fig. 117 Case 70.

Hydronephrosis.

Ascending pyelogram shows marked dilatation of right renal pelvis. Calyceal and parenchymal detail absent.

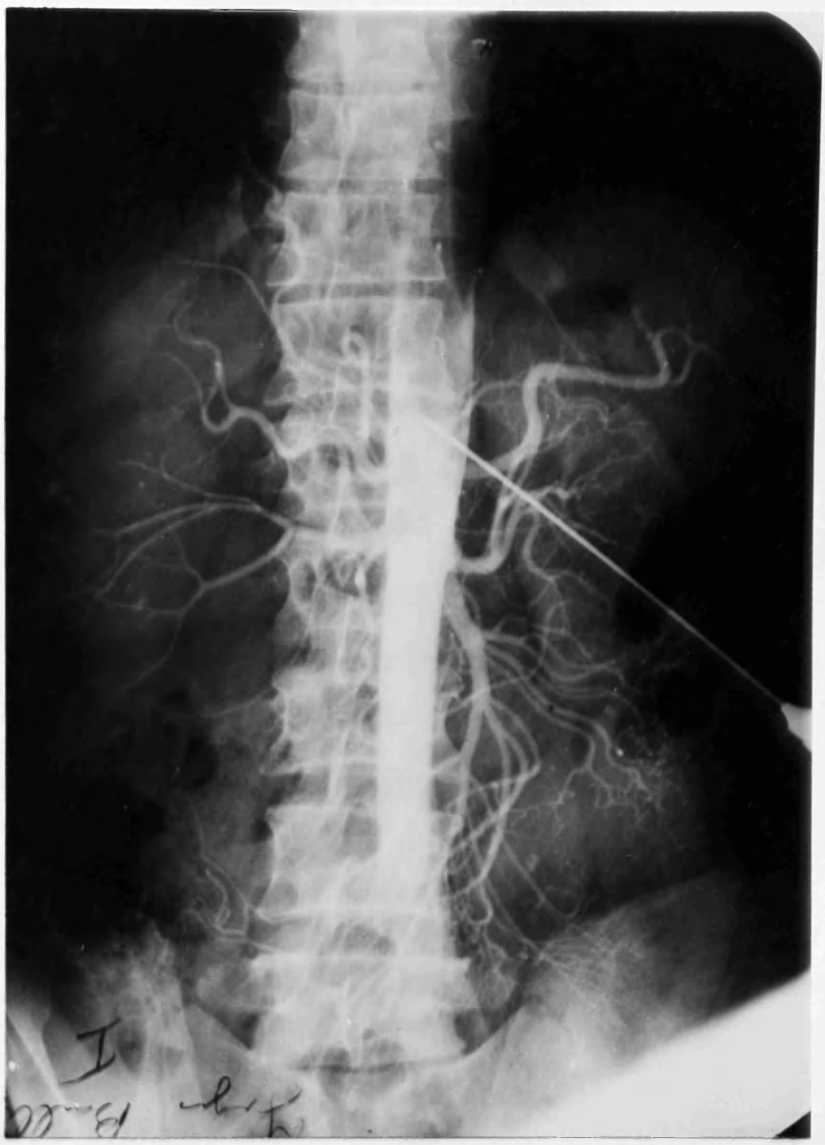

Fig. 118 Case 70.

Hydronephrosis.

Arteriogram shows attenuation and displacement of main vessels to right kidney. Note aberrant artery to lower pole.

Fig. 119 Case 71.

Hydronephrosis.

Ascending pyelograms show slight dilatation of left kidney and faint outline of considerably dilated right kidney.

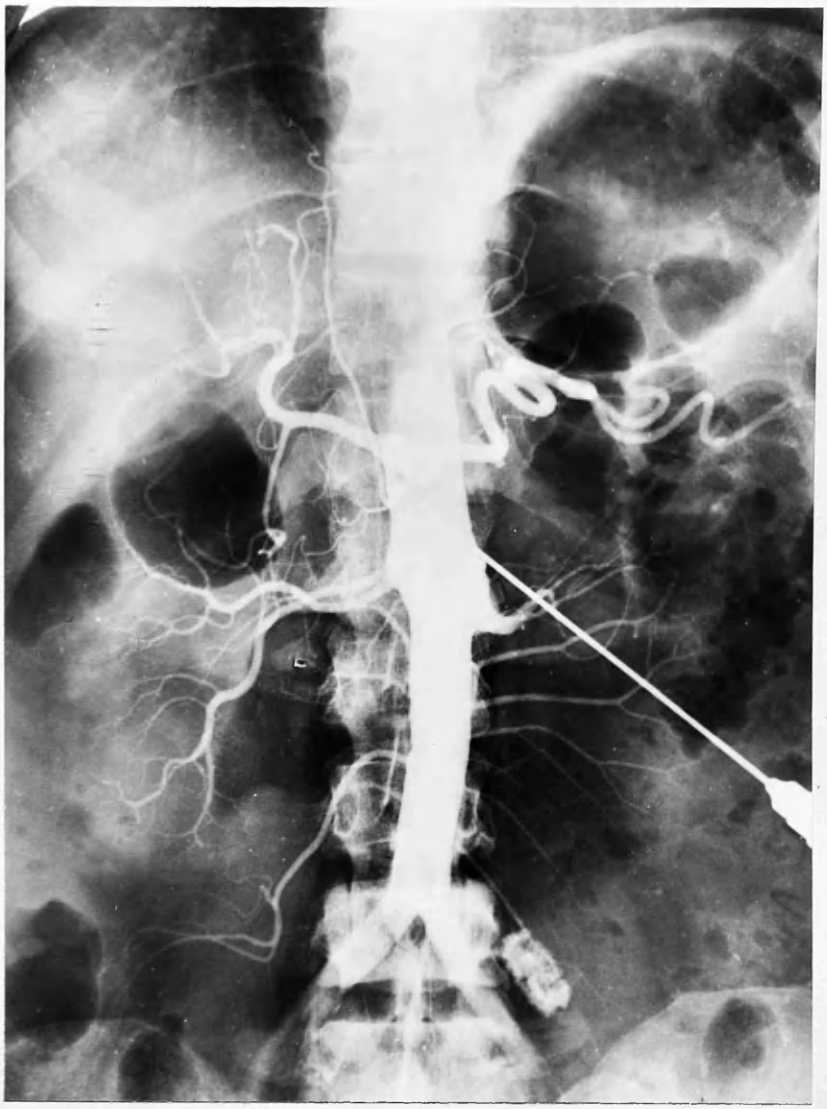

Fig. 120 Case 71.

Hydronephrosis.

Arteriogram shows gross vascular deficiency to the left kidney. The right kidney has a double blood supply, the total vascularity being reasonably good. Note aortic irregularity due to athero-sclerosis.

Fig. 121 Case 71.

Hydronephrosis.

Nephrogram shows right kidney to be enlarged with reduced parenchymal density. No nephrogram effect on the left side.

AORTOGRAPHY IN DIAGNOSIS

VOLUME FOUR

ILLUSTRATIONS

C O N T E N T S

VOLUME IV

Fig. 122 Case 72.

Hydrocalicosis.

Ascending pyelogram shows dilatation of upper calyx of right kidney.

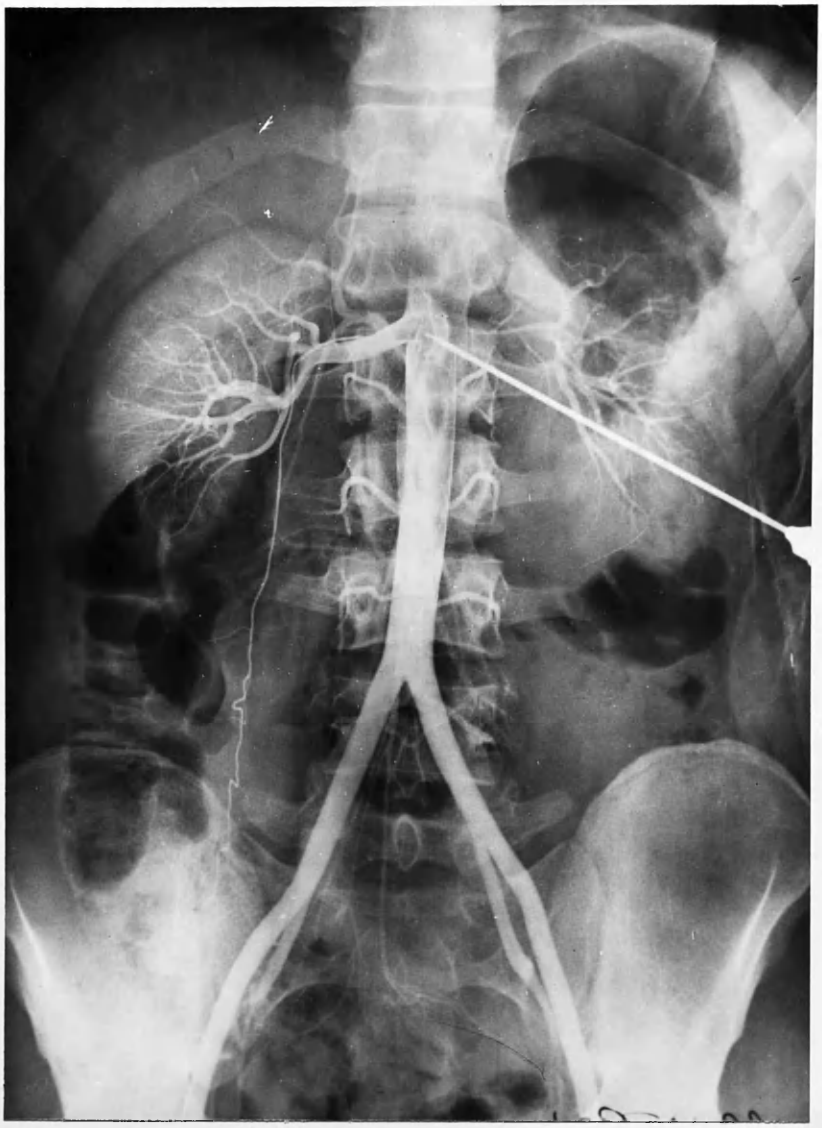

Fig. 123 Case 72.

Hydrocalicosis.

Arteriogram shows normal vascularity of right kidney.
Two extra-renal branches supply the upper pole.
Note right spermatic artery.

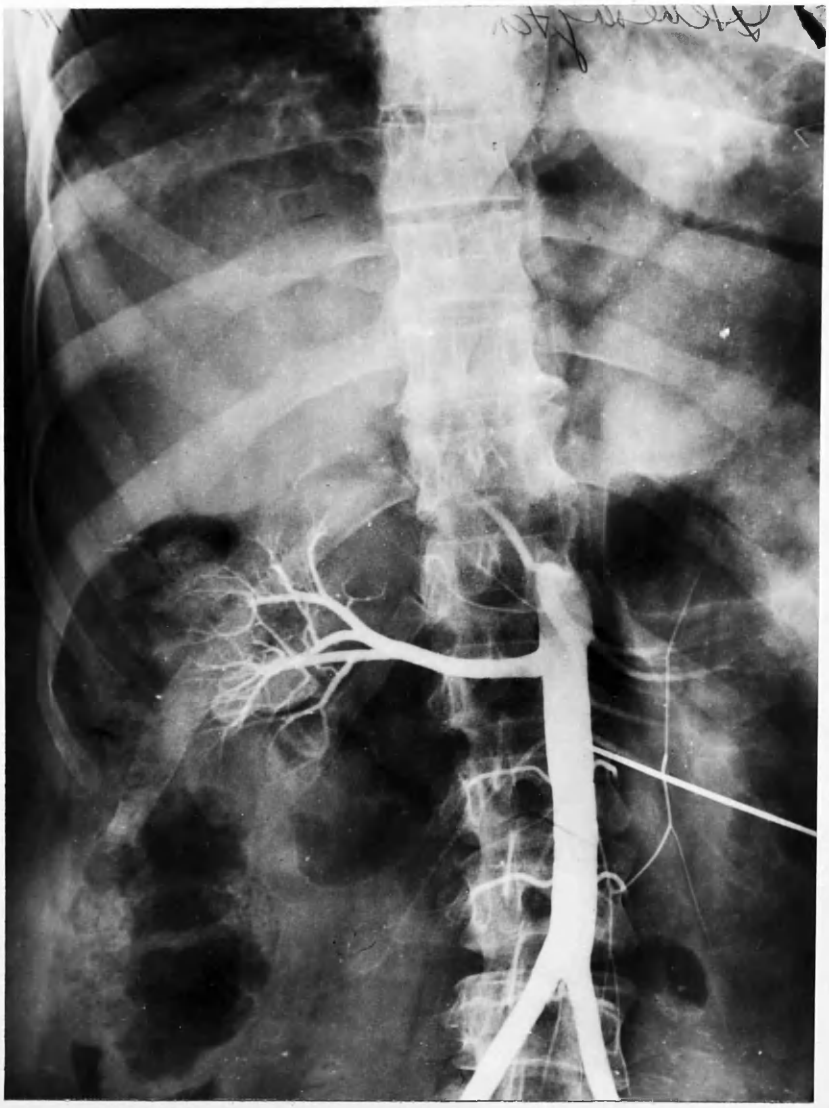

Fig. 124 Case 73.

Hydrocalicosis.

Arteriogram shows poor vascularity in the lower pole with no cortical arborisation. Note stump of left renal artery and needle placed well below renal artery origin.

Fig. 125 Case 73.

Hydrocalicosis.

Nephrogram shows relative translucency of lower pole due to impaired vascularity.

Fig. 126 Case 74.

Hydrocalicosis.

Ascending pyelogram shows dilatation of right upper calyx with attenuated neck.

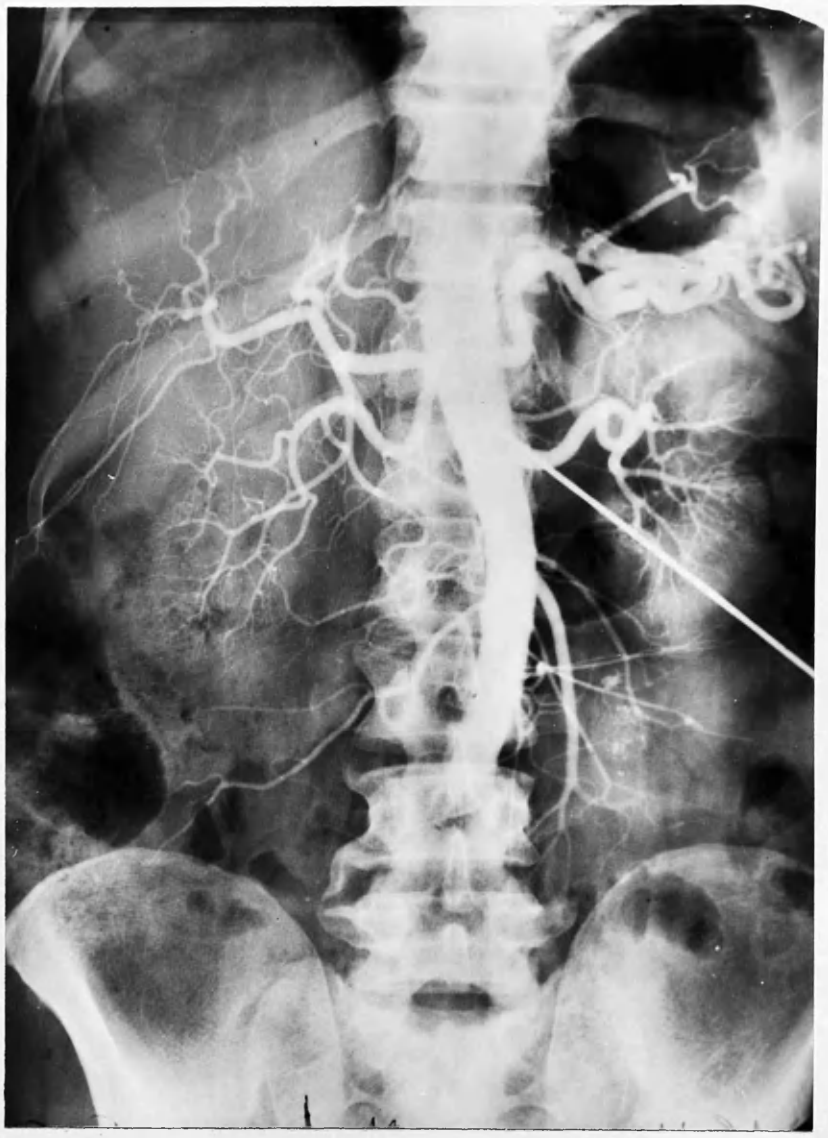

Fig. 127 Case 74.

Hydrocalicosis.

Arteriogram shows good blood supply to right kidney with slight reduction in cortical branching at upper pole.

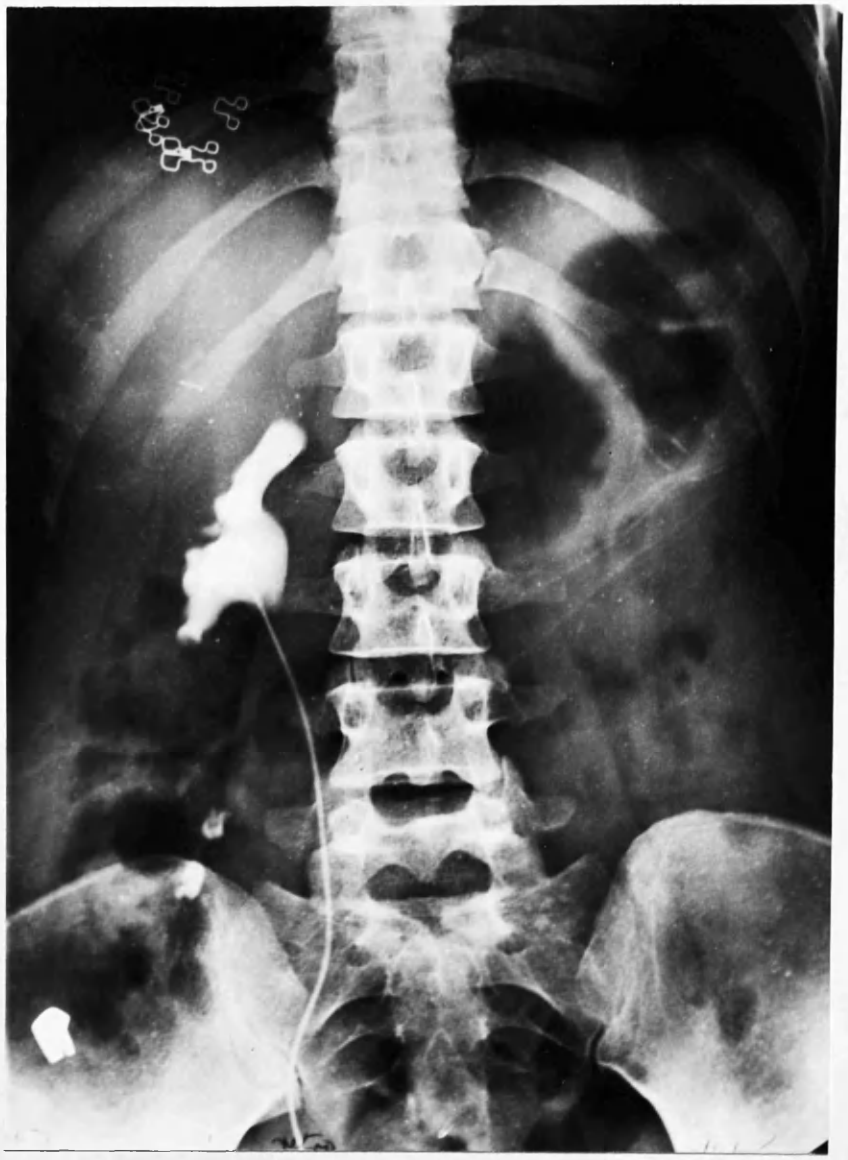

Fig. 128 Case 75.

Hydrocalicosis.

Ascending pyelogram shows dilatation of right upper calyx group.

Fig. 129 Case 75.

Hydrocalicosis.

Arteriogram shows slight vascular deficiency in right upper pole. Note right inferior adrenal artery arising from main renal vessel.

Fig. 130 Case 76.

Calculus.

Arteriogram shows double blood supply to right kidney. Both vessels small with no appreciable parenchymal branching - calculus hydronephrosis.

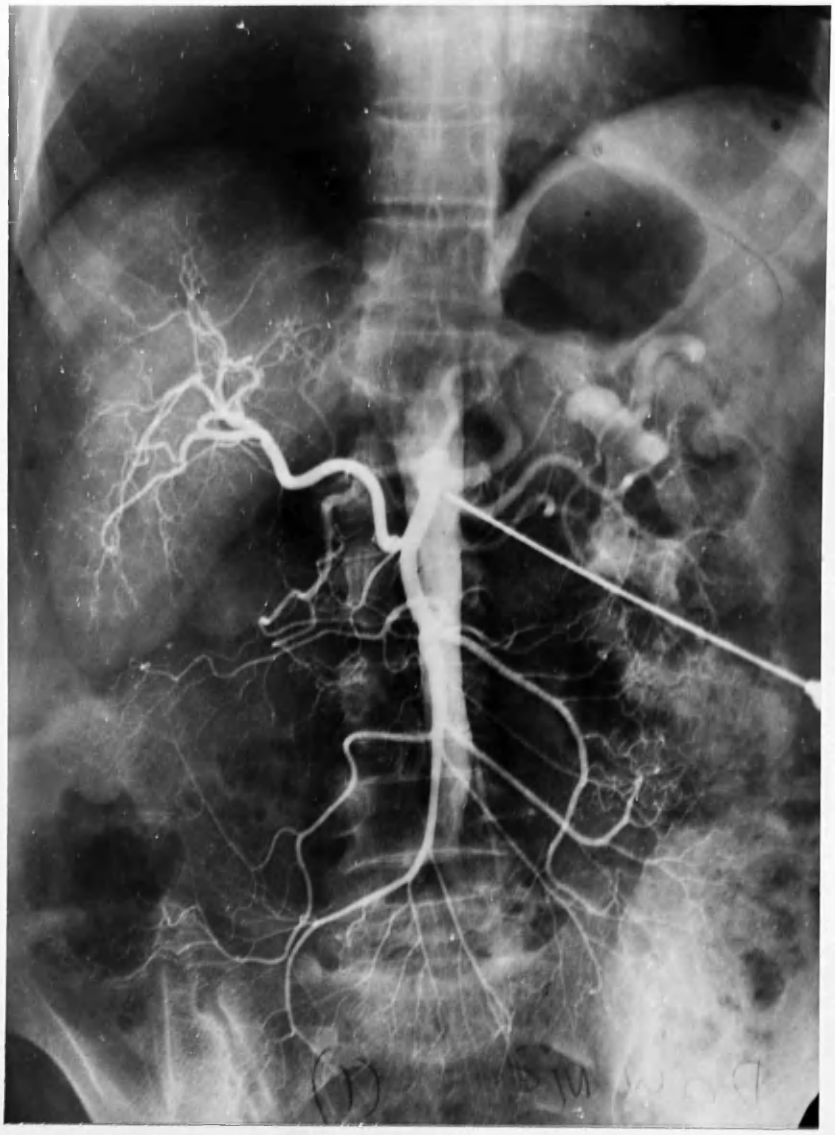

Fig. 131 Case 77.

Calculus.

Arteriogram shows double blood supply to left kidney containing stone. No appreciable right renal vascularity. Note hepatic artery arising from superior mesenteric artery.

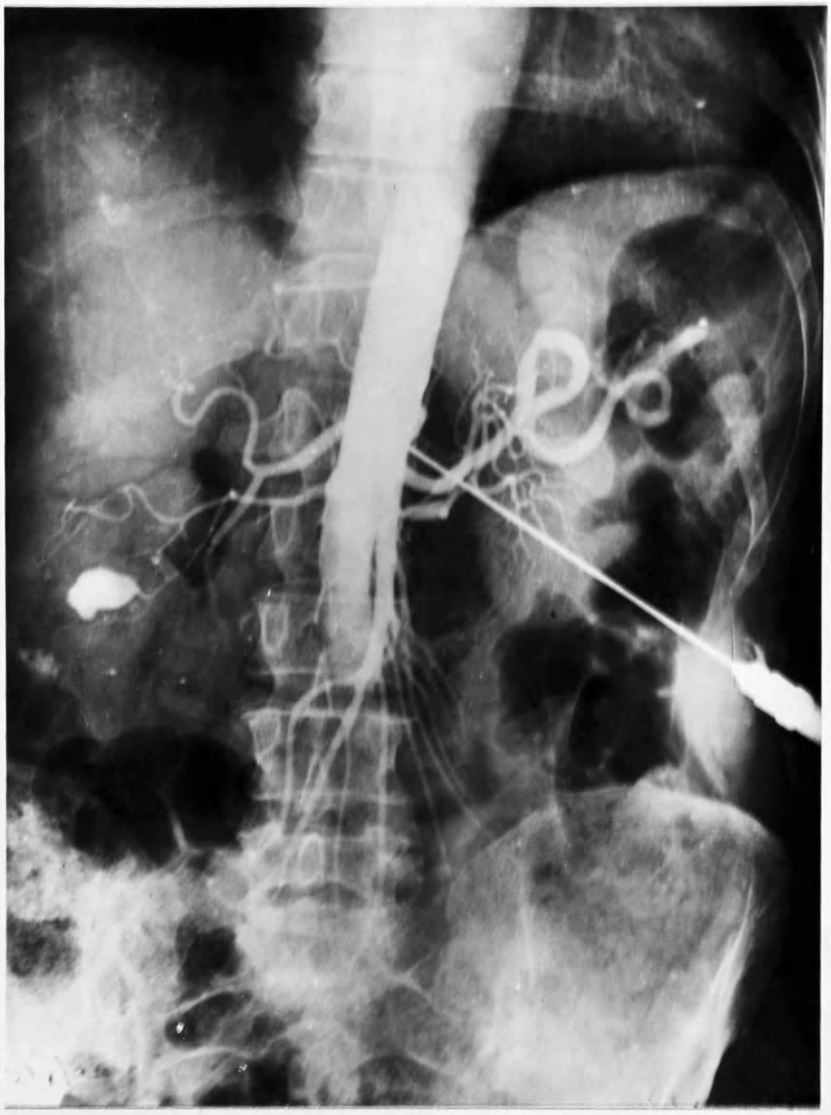

Fig. 132 Case 78.

Calculus.

Arteriogram shows attenuation of right renal artery and its divisions - calculus hydronephrosis. Note atherosclerosis affecting left renal artery.

Fig. 133 Case 79

Calculus.

Arteriogram shows reduction in vascularity of right kidney - calculus hydronephrosis.

Fig. 134 Case 81.

Calculus.

Ascending pyelogram shows calculus hydronephrosis with cut-off at uretero-pelvic junction.

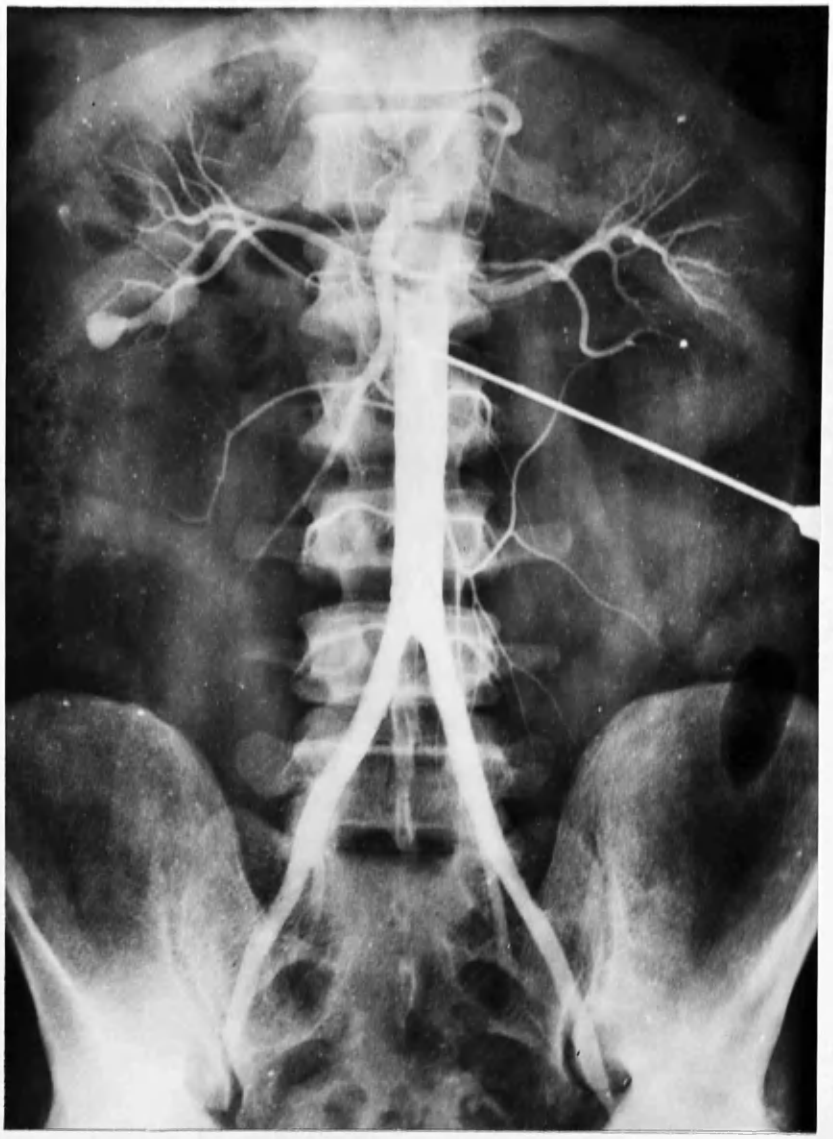

Fig. 135 Case 81.

Calculus.

Arteriogram shows satisfactory main blood supply to right kidney. Terminal branches in lower pole are displaced by the calyceal dilatation.

Fig. 136 Case 82.

Calculus.

Ascending pyelogram shows right bifid pelvis.

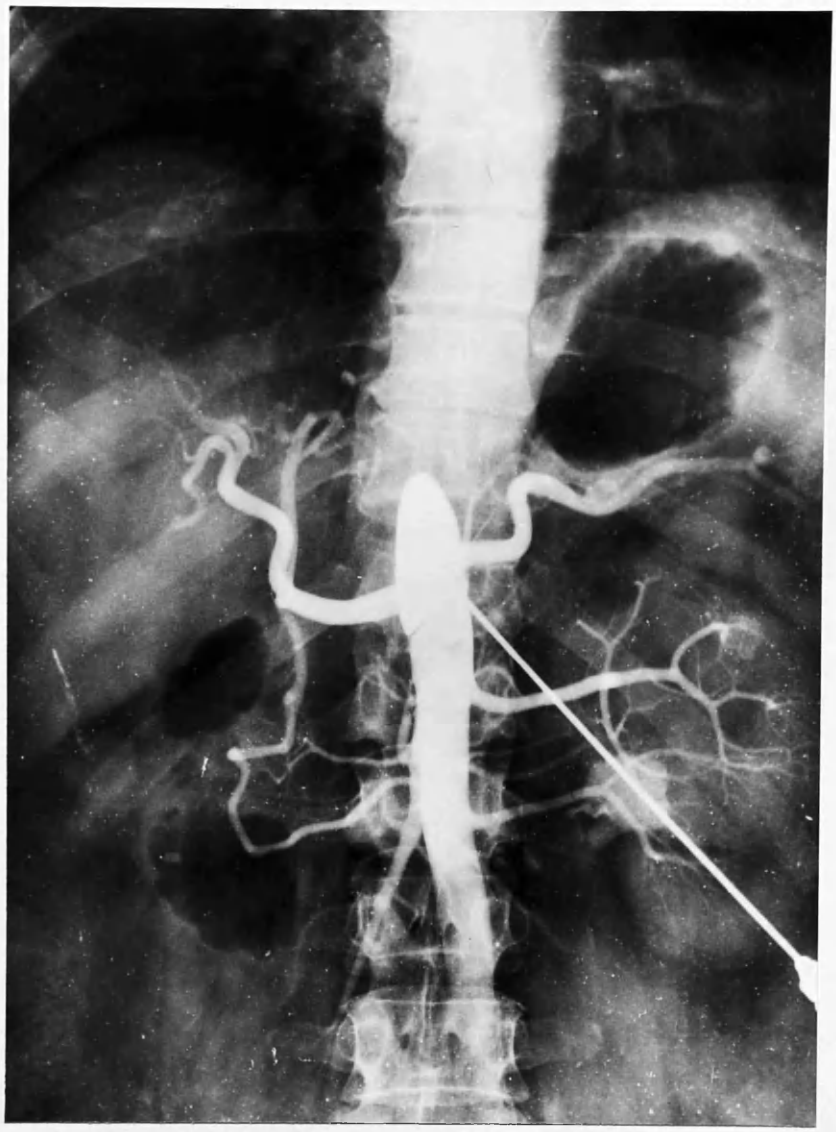

Fig. 137 Case 82.

Calculus.

Arteriogram shows double blood supply to left kidney with a degree of cortical deficiency due to hydronephrosis. Right renal artery is very small and parenchymal vasculature absent.

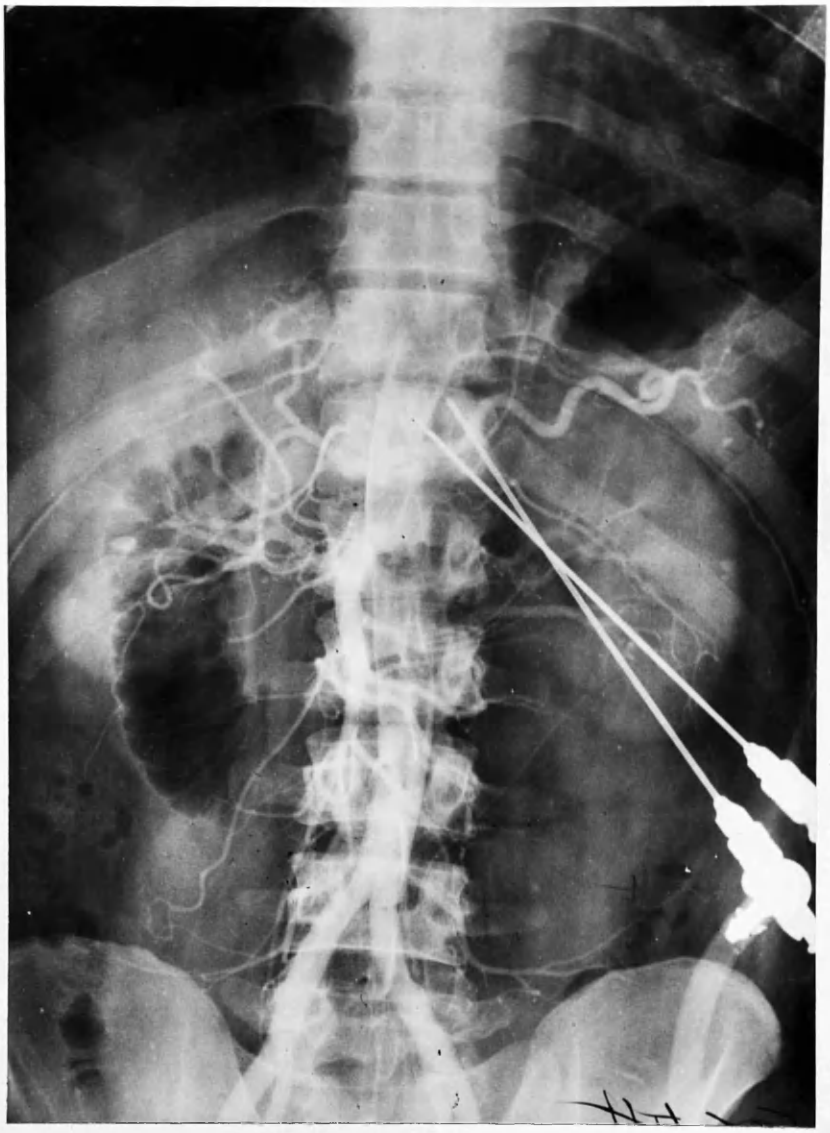

Fig. 138 Case 83.

Calculus.

Arteriogram shows double blood supply to left kidney. Crossed needles used in pressure experiments.

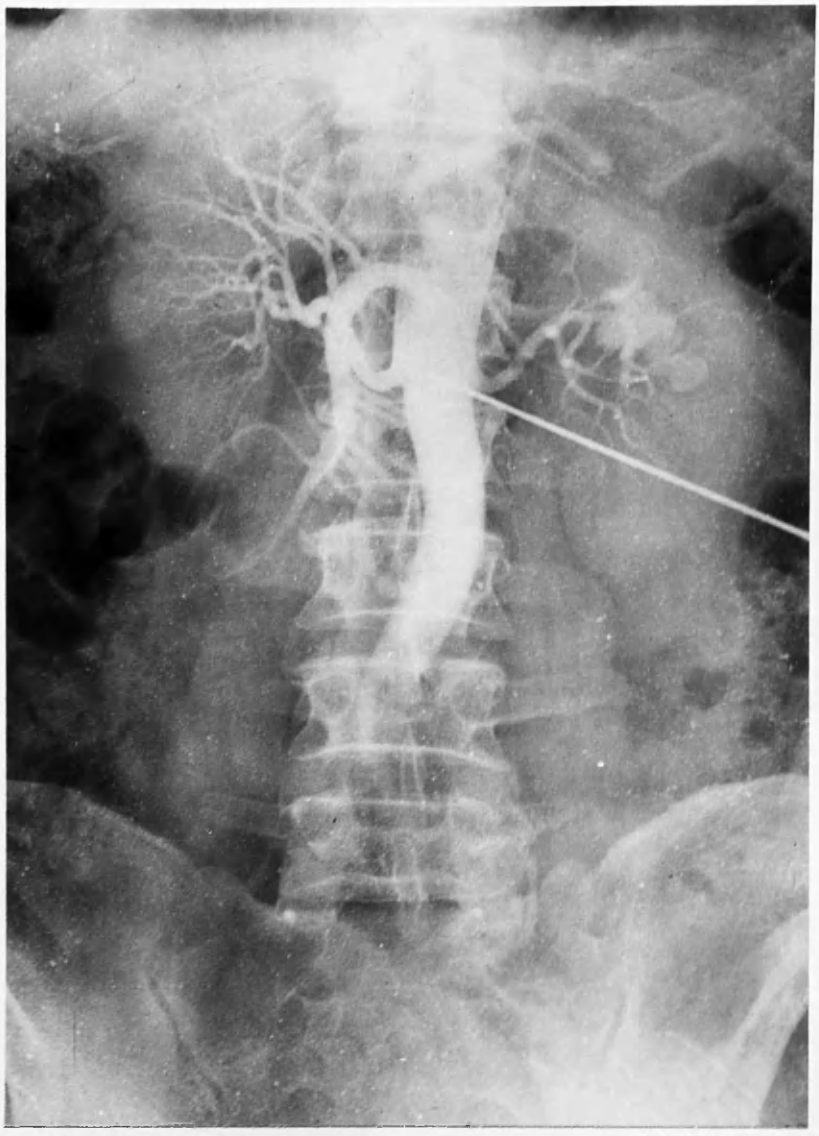

Fig. 139 Case 84.

Calculus.

Arteriogram shows good main blood supply to left kidney containing stone. Cortical branching considerably reduced.

Fig. 140 Case 85.

Calculus.

Excretion urogram shows incomplete rotation and dilatation of left kidney. Moderate extra-renal dilatation on right side.

Fig. 141 Case 85.

Calculus.

Arteriogram shows good supply to left kidney with stone apparently in lower pole. Note aberrant artery to right lower pole.

Fig. 142 Case 85.

Calculus.

Nephrogram shows stone to lie nearer renal pelvis than lower calyx.

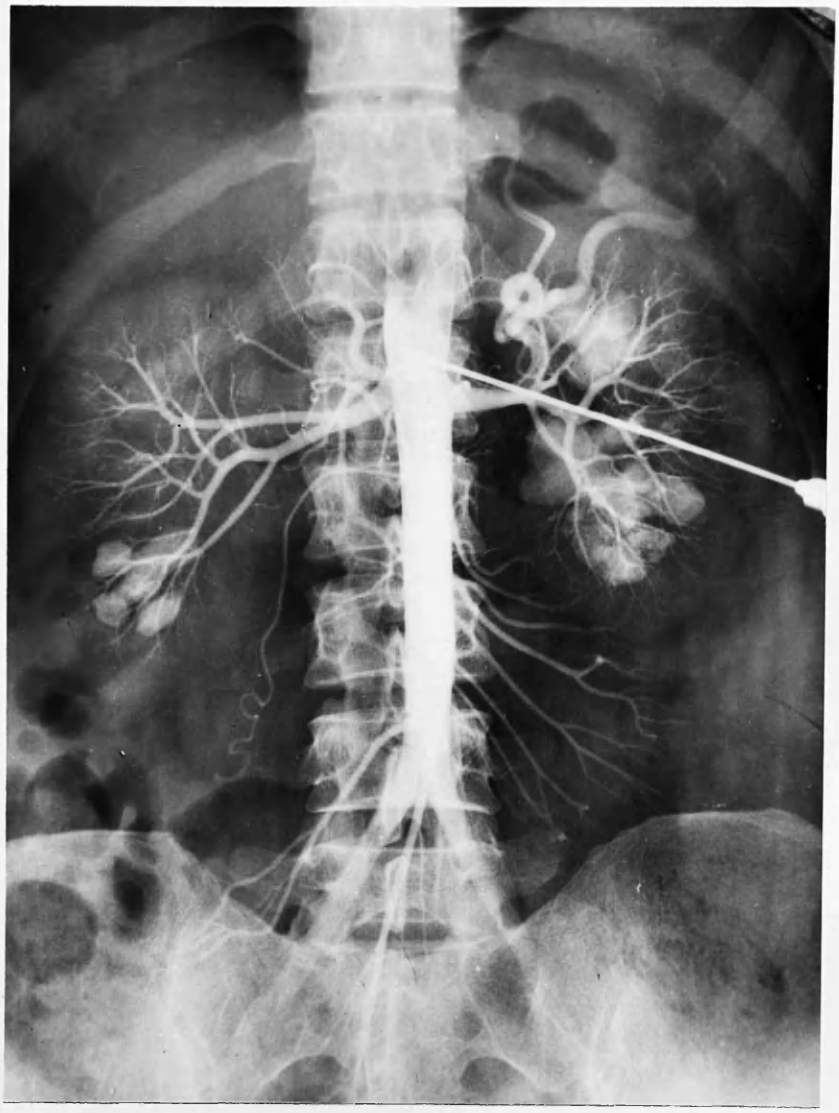

Fig. 143 Case 86.

Calculus.

Arteriogram shows good blood supply to both kidneys in spite of massive calculus formation on left side. Feasibility of extra-renal ligation of vessels for resection of lower poles clearly shown.

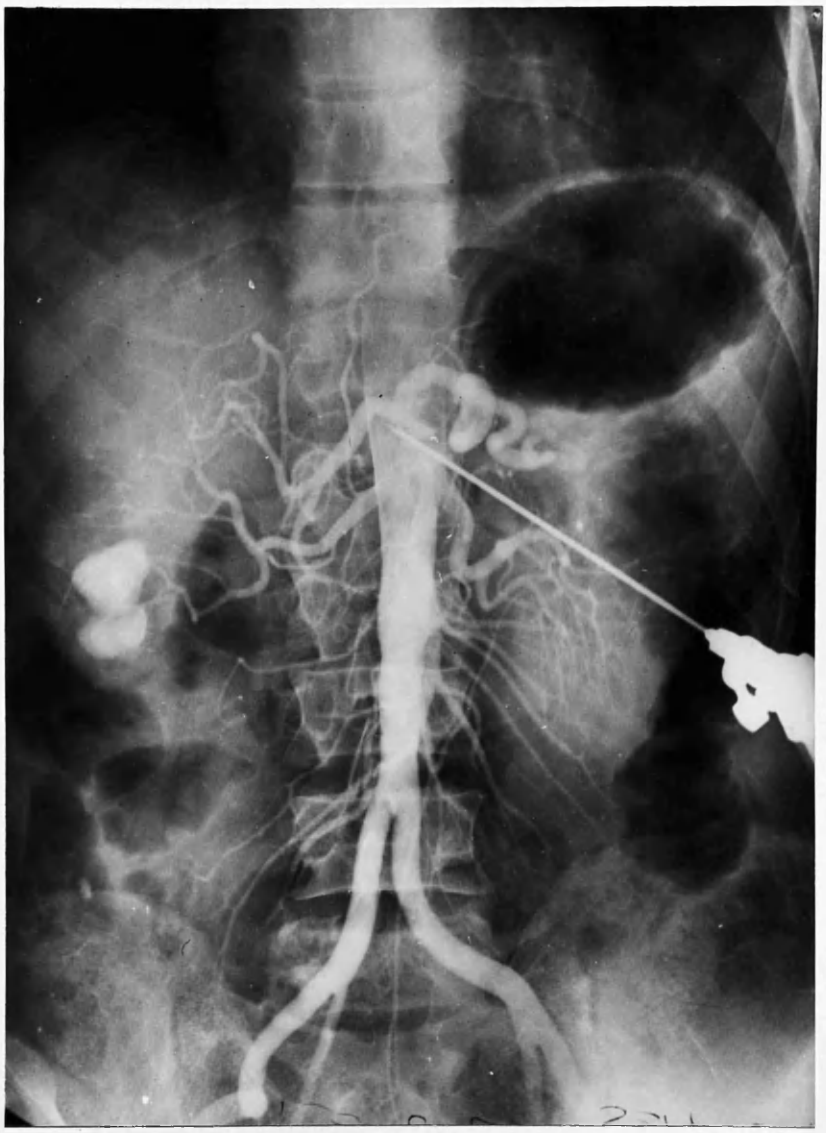

Fig. 144 Case 87.

Calculus.

Arteriogram shows satisfactory main blood supply to upper part of right kidney. Feasibility of extra-renal ligation for resection of lower pole demonstrated.

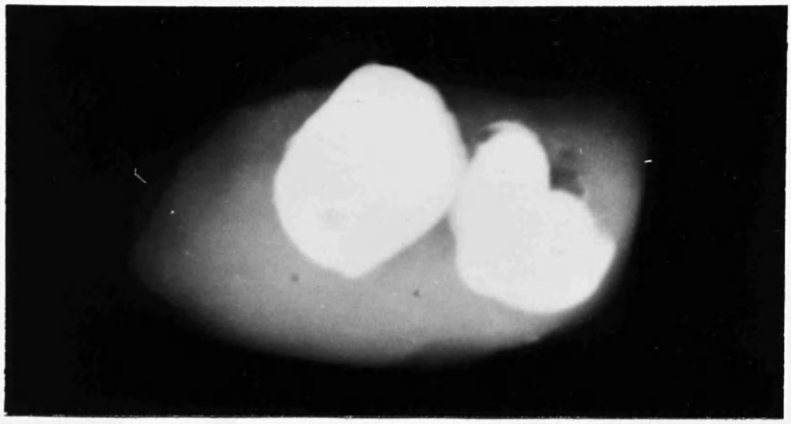

Fig. 145 Case 87.

Renal Calculus.

Resected tissue containing stones in dilated calyces.

Fig. 146 Case 88.

Renal Calculus.

Resected tissue containing stone in dilated calyx.

Fig. 147 Case 88.

Calculus.

Ascending pyelogram shows stone in dilated lower calyx of left kidney.

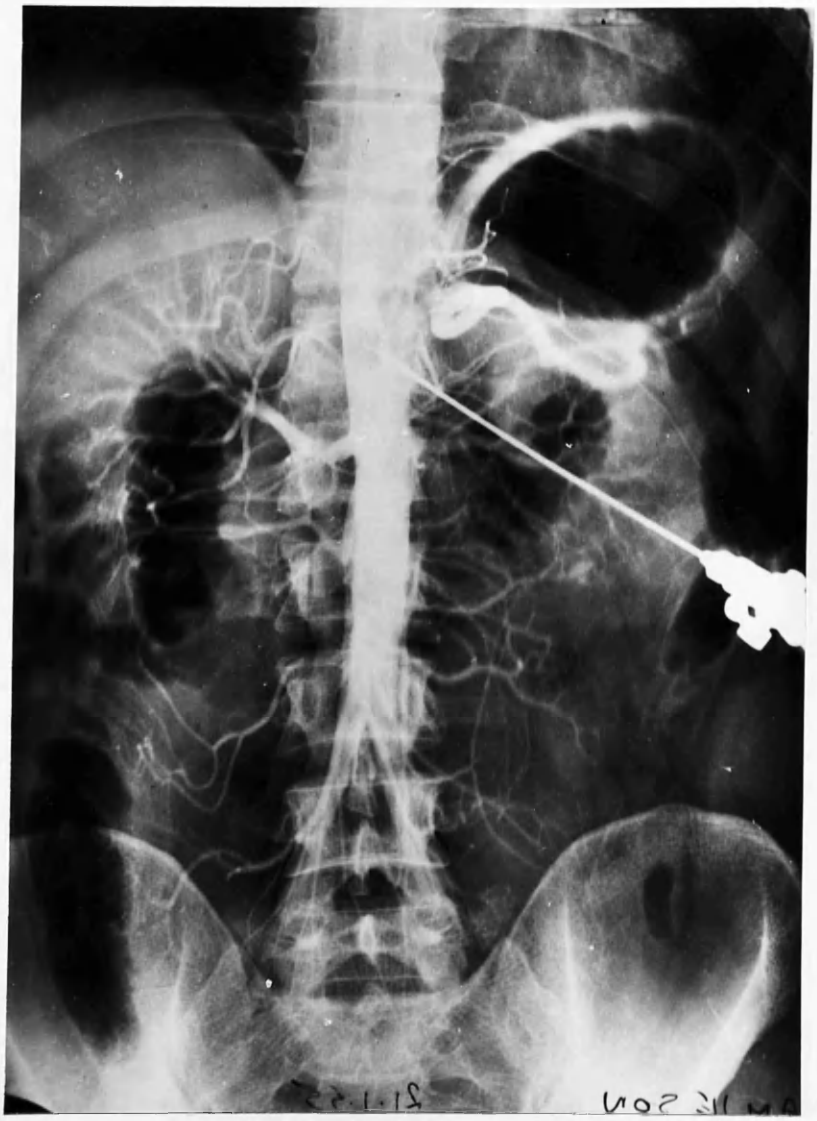

Fig. 148 Case 88.

Calculus.

Arteriogram shows double blood supply to left kidney. Accessory vessel to lower pole containing stone constitutes main supply to this part.

Fig. 149 Case 88.

Calculus.

Nephrogram shows relation of stone to parenchyma of left kidney.

Fig. 150 Case 89.

Calculus.

Arteriogram shows satisfactory vascularity of right kidney and blood supply to lower pole containing two small stones.

Fig. 151 Case 90.

Calculus.

Arteriogram shows adequate blood supply to left kidney.
No vessel to upper pole amenable to extra-renal ligation.

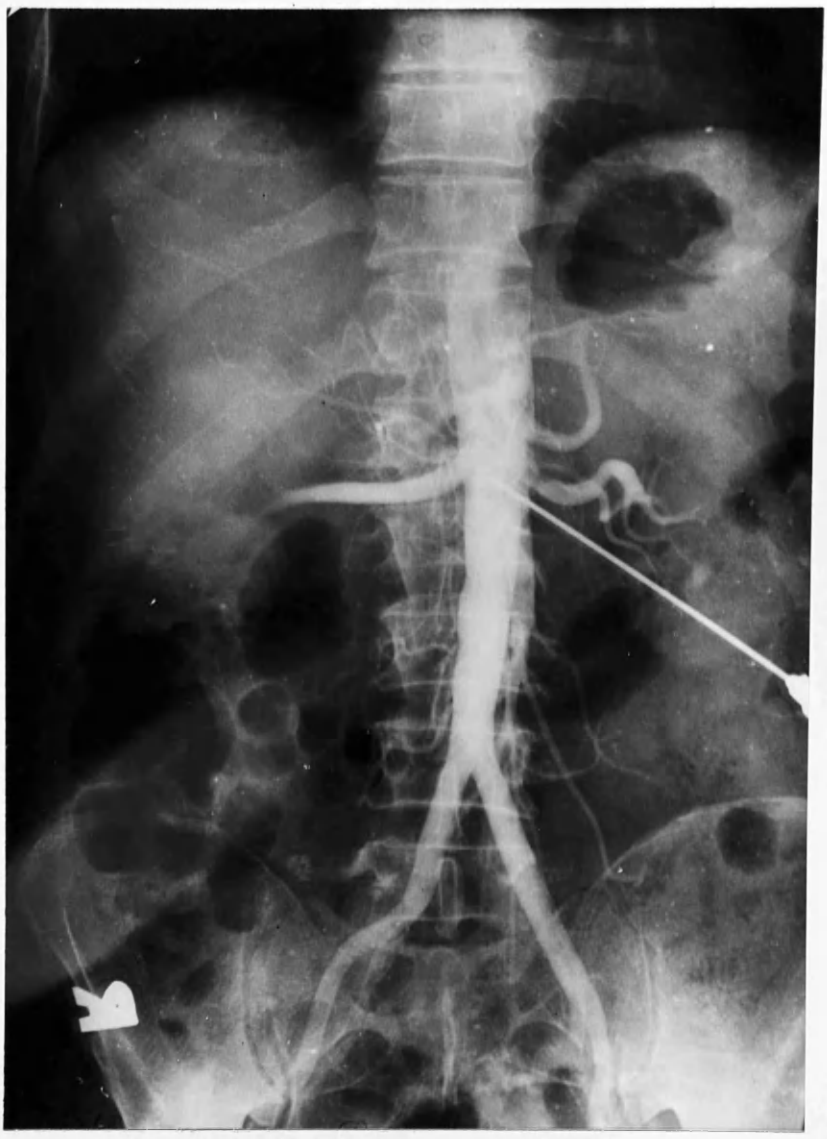

Fig. 152 Case 91.

Calculus.

Arteriogram shows adequate blood supply to left kidney, and a branch suitable for extra-renal ligation.

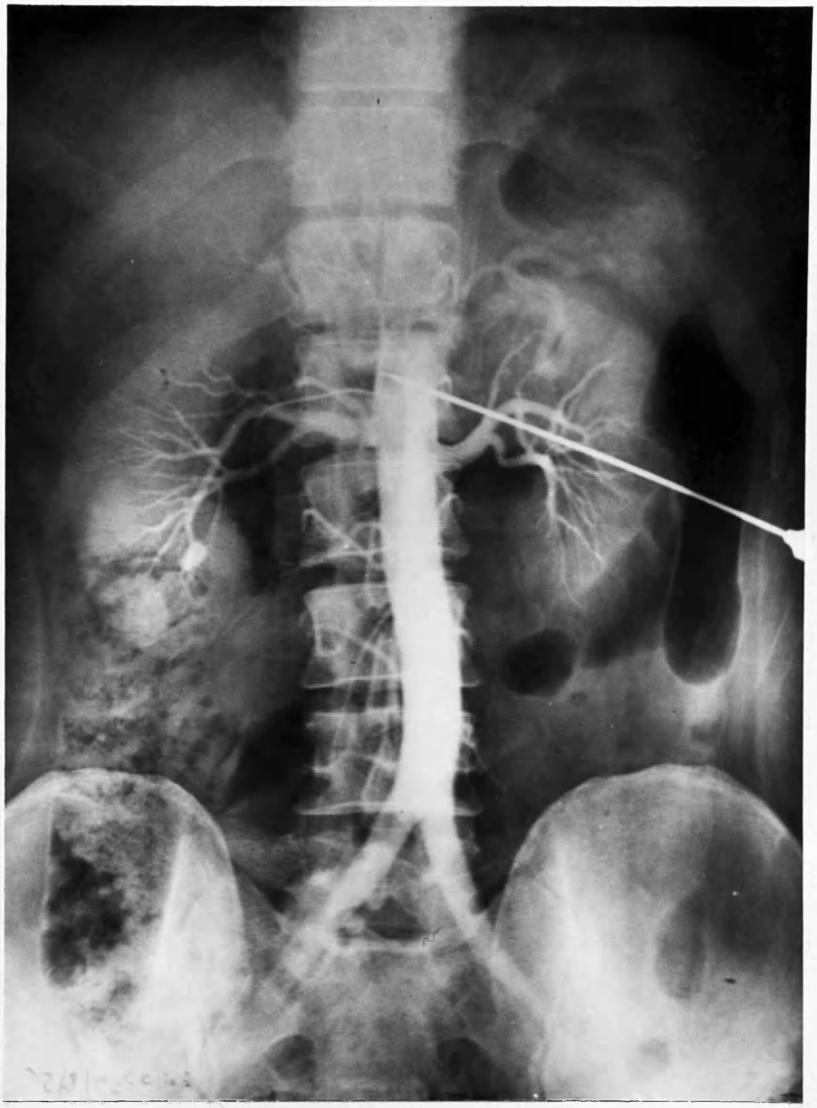

Fig. 153 Case 92.

Calculus.

Arteriogram shows good blood supply to right kidney.
No vessel to lower pole suitable for extra-renal ligation.

Fig. 154 Case 93.

Calculus.

Arteriogram shows vessel to right lower pole containing stone suitable for extra-renal ligation before resection.

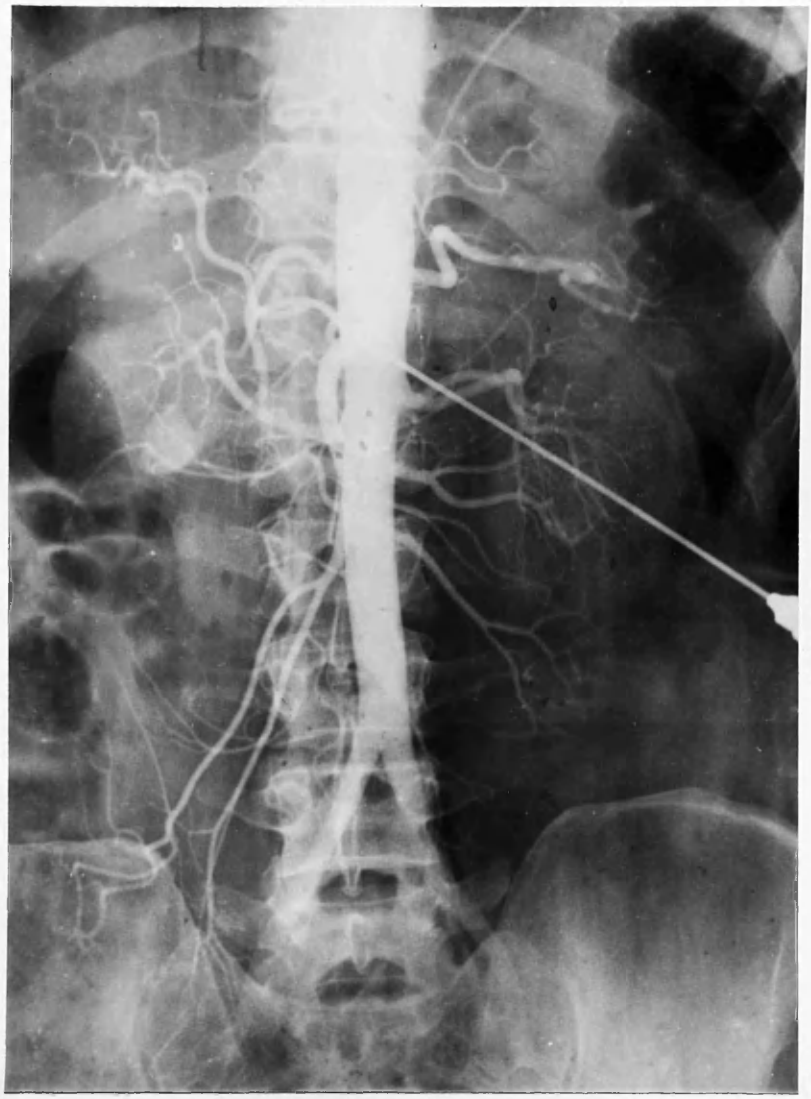

Fig. 155 Case 94.

Calculus.

Arteriogram shows blood supply to high-lying right kidney. No vessel to lower pole suitable for extra-renal ligation.

Fig. 156 Case 95.

Renal Tuberculosis.

Ascending pyelograms show small irregular filling defects in the upper left calyces.

Fig. 157 Case 95.

Renal Tuberculosis.

Arteriogram shows double blood supply to left kidney. There is some vascular irregularity near the upper pole but no atrophy or ischaemia.

Fig. 158 Case 95.

Renal Tuberculosis.

Nephrogram shows condensation of dye around left upper calyces.

Fig. 159 Case 96.

Renal Tuberculosis.

Ascending pyelograms show ulcero-cavernous lesions affecting right lower calyces.

Fig. 160 Case 96.

Renal Tuberculosis.

Arteriogram shows condensation of dye near right lower calyces with decrease in cortical branching beyond that point.

Fig. 161 Case 97.

Renal Tuberculosis.

Ascending pyelograms show lesions affecting left upper and lower calyx group. Middle calyx group not shown.

Fig. 162 Case 97.

Renal Tuberculosis.

Arteriogram shows vascular deficiency of the middle segment of the left kidney.

Fig. 163 Case 97.

Renal Tuberculosis.

Nephrogram shows wedge-shaped area of ischaemia in middle segment of left kidney.

Fig. 164 Case 99.

Renal Tuberculosis.

Excretion urogram shows poor definition of right lower calyx group. There is erosion of the left lower calyx and obliteration of part of the middle group.

Fig. 165 Case 99.

Renal Tuberculosis.

Arteriogram shows vascular deficiency of right lower pole. There is a double blood supply to left kidney with abrupt ending of major branches in middle and lower segments. Considerable overlay from mesenteric branches.

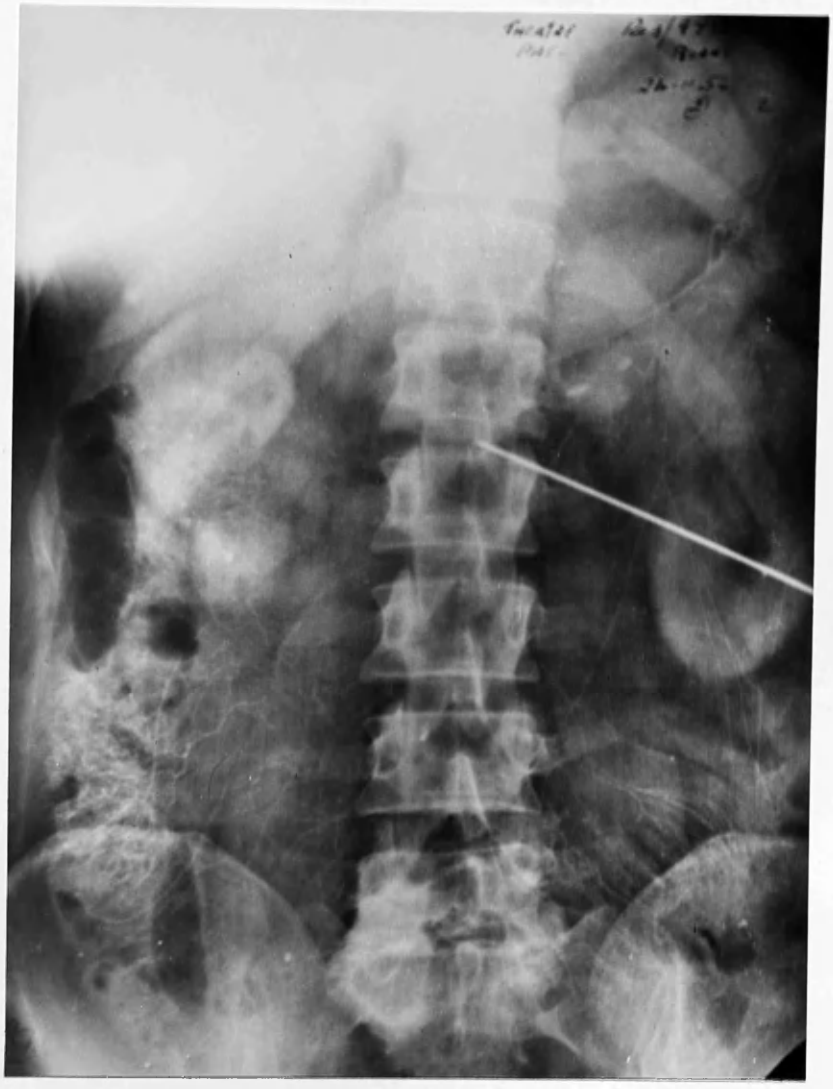

Fig. 166 Case 99.

Renal Tuberculosis.

Nephrogram defines irregularity and bossing of both kidneys. Areas of ischaemia are present in the left parenchyma.

Fig. 167 Case 100.

Renal Tuberculosis.

Excretion urogram shows dilatation of right calyces and ureter. No dye present on left side.

Fig. 168 Case 100.

Renal Tuberculosis.

Arteriogram shows four arteries to right kidney. The upper half only has a good vascularity but with poor cortical arborisation. Gross vascular deficiency of left kidney.

Fig. 169 Case 101.

Renal Tuberculosis.

Ascending pyelograms show dilatation of right calyces. Failure to outline left kidney.

Fig. 170 Case 101.

Renal Tuberculosis.

Nephrogram shows bossing and areas of ischaemia especially on the left side.

Fig. 171 Case 102.

Renal Tuberculosis.

Arteriogram shows no blood supply to calcified left kidney only the stump of the renal artery remaining. Double supply to right kidney but vessels thinned and displaced due to dilatation.

Fig. 172 Case 103.

Renal Tuberculosis.

Ascending pyelogram shows lesions affecting the left middle and lower calyces. Calcification of right kidney.

Fig. 173 Case 103.

Renal Tuberculosis.

Arteriogram shows good blood supply to left kidney with thickened main branches. Two small areas of calcification are present. No vascularity to right kidney.

Fig. 174 Case 104.

Renal Tuberculosis.

Arteriogram shows double blood supply to right kidney. Parenchymal vascularity is poor, the main vessels ending abruptly with no cortical branching.

Fig. 175 Case 105.

Renal Tuberculosis.

Arteriogram shows thickening of interlobar branches in right upper pole. Blurring due to respiratory movement.

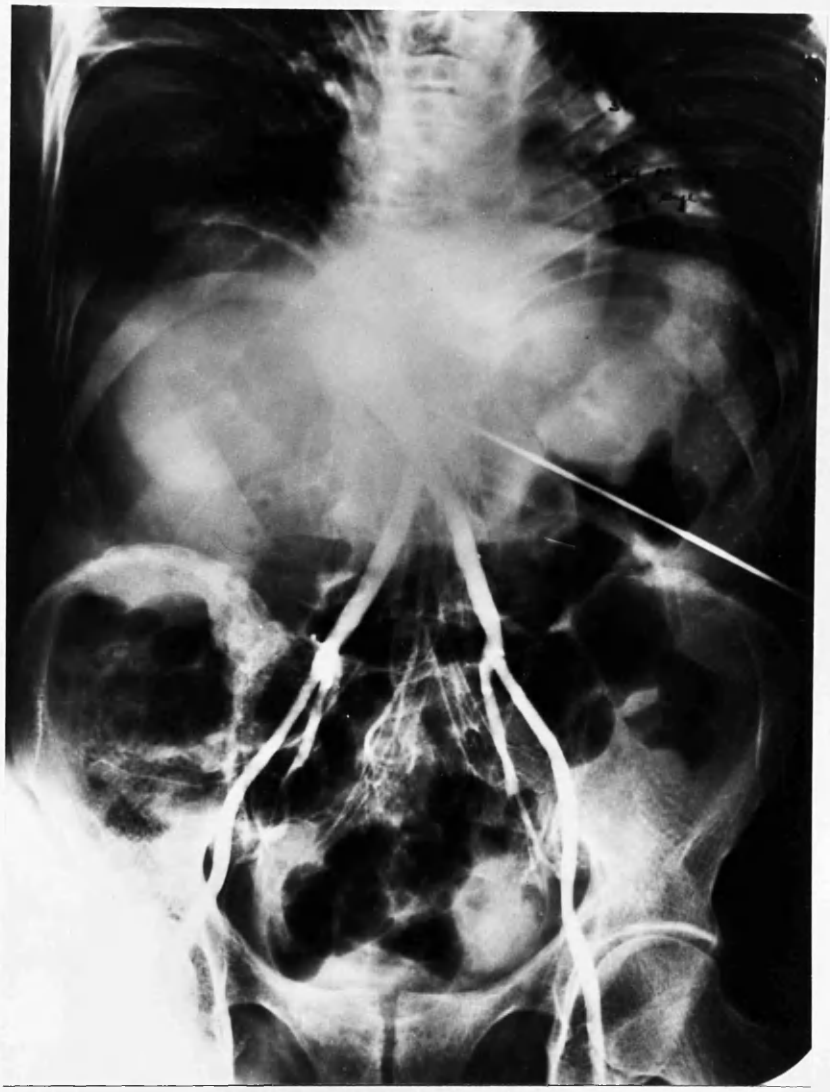

Fig. 176 Case 106.

Renal Tuberculosis.

Arteriogram performed on advanced case of spinal deformity. No useful renal information gained due to poor X-Ray penetration.

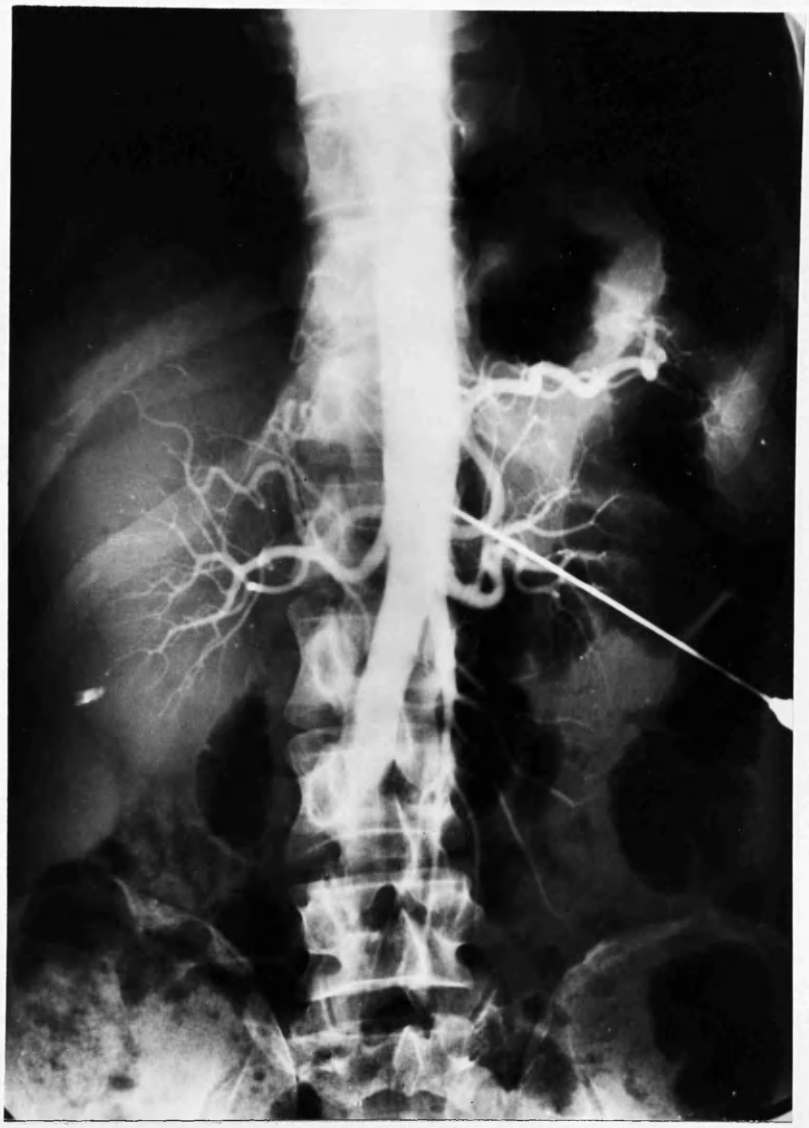

Fig. 177 Case 107.

Renal Tuberculosis.

Arteriogram shows no diagnostic changes in the right kidney.

Fig. 178 Case 108.

Renal Tuberculosis.

Arteriogram shows no diagnostic changes in the left kidney.

Fig. 179 Case 109.

Renal Tuberculosis.

Arteriogram shows good blood supply to affected left kidney. Although branches are separated, indicative of calyceal dilatation, this not exclusively diagnostic of tuberculosis.

Fig. 180 Case 110.

Renal Hypoplasia.

Arteriogram shows a tiny right renal artery with two thin major divisions.

Fig. 181 Case 110.

Renal Hypoplasia.

Nephrogram shows absence of functioning parenchyma on the right side.

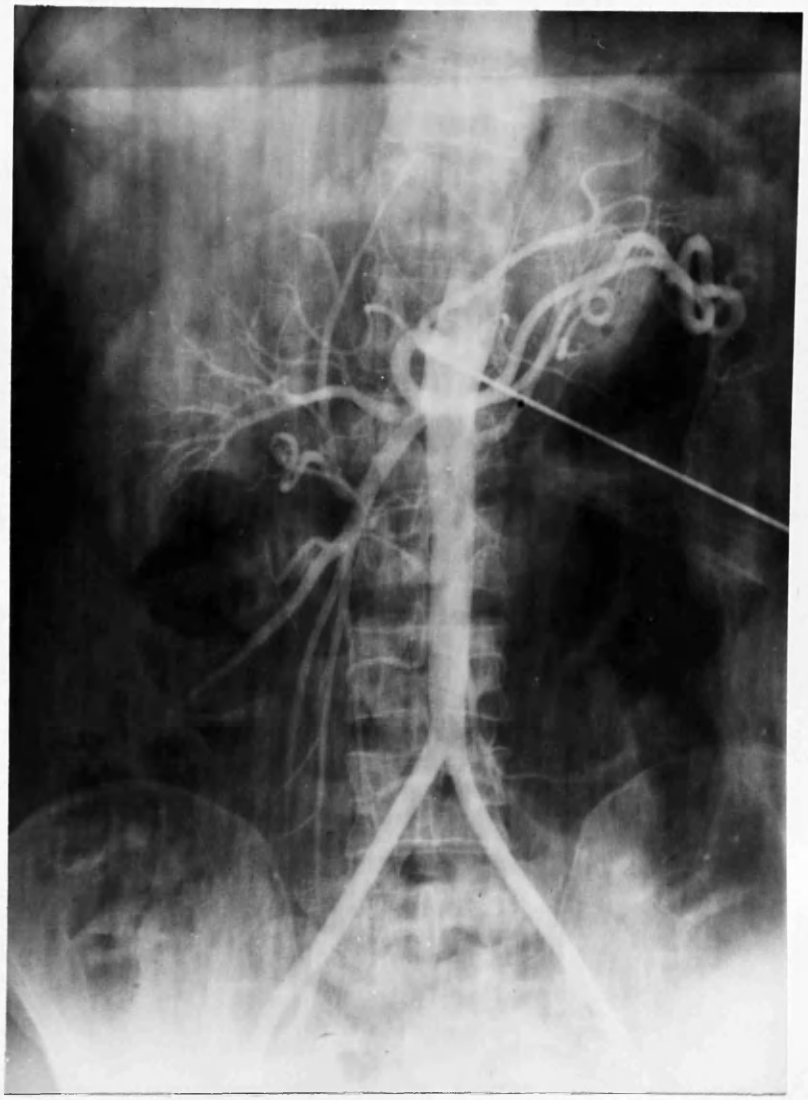

Fig. 182 Case 111.

Renal Hypoplasia.

Arteriogram shows vascularity of left kidney to be reduced and constricted.

Fig. 183 Case 112.

Renal Hypoplasia.

Arteriogram shows a double blood supply to the small right kidney. Both vessels are extremely small and no cortical supply is evident.

Fig. 184 Case 113.

Post-operative Function.

Uretero-colic anastomosis of congenital solitary right kidney. Arteriogram shows normal vascularity on right side.

Fig. 185 Case 114.

Post-operative Function.

Uretero-colic anastomosis of solitary right kidney - left nephrectomy for tuberculosis.
Arteriogram shows good vascularity of remaining kidney.

Fig. 186 Case 115.

Post-operative Function.

Plastic repair for left hydronephrosis.
Arteriogram shows vascular deficiency on left side. Note aberrant artery to lower pole.

Fig. 187 Case 116.

Post-operative Function.

Arteriogram shows endarteritis obliterans of right renal artery, only the stump of which is shown. Good hypertrophied left renal vascularity.

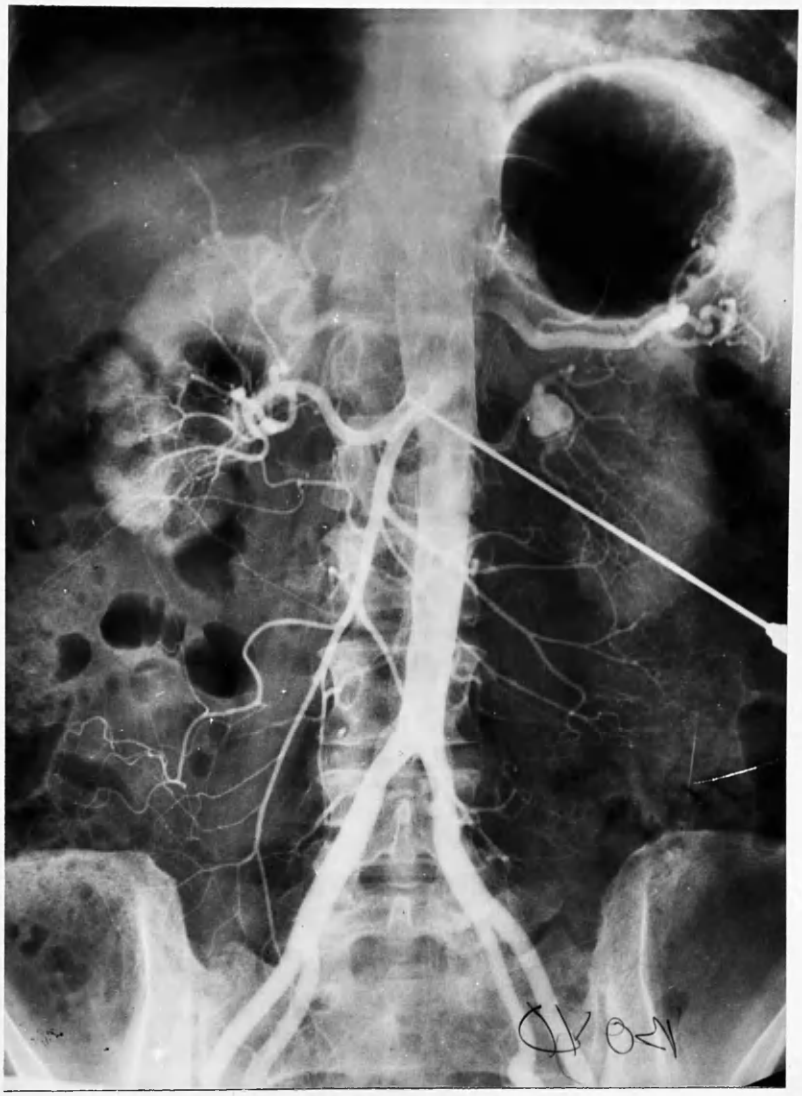

Fig. 188 Case 117.

Renal Artery Aneurysm.

Arteriogram shows saccular aneurysm of left renal artery also saccular aneurysm of the branches of the right renal artery, splenic and hepatic arteries.

Fig. 189 Case 118.

Renal Trauma.

Arteriogram shows good main blood supply to right kidney but poor vascularity of upper pole.

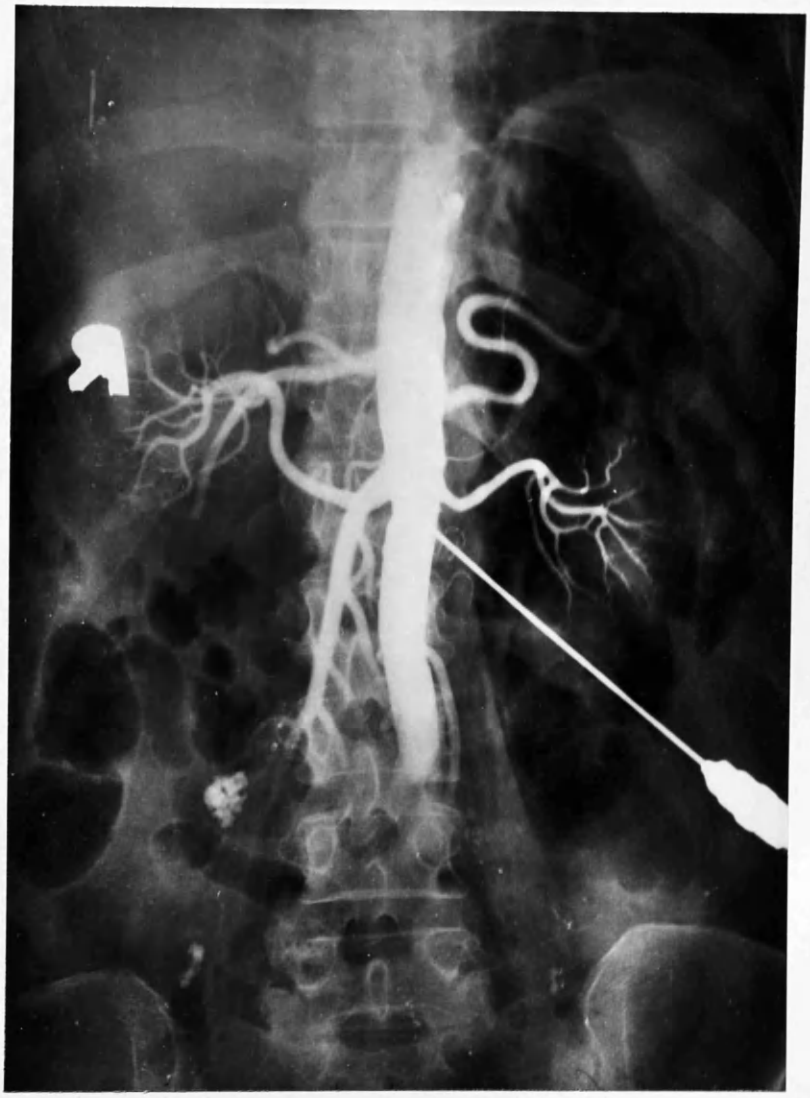

Fig. 190 Case 119.

Adrenal Cortical Hyperplasia.

Arteriogram shows normal left adrenal artery.

Fig. 191 Case 119.

Adrenal Cortical Hyperplasia.

Nephrogram phase shows tendency to "cocked-hat" appearance but no appreciable enlargement.

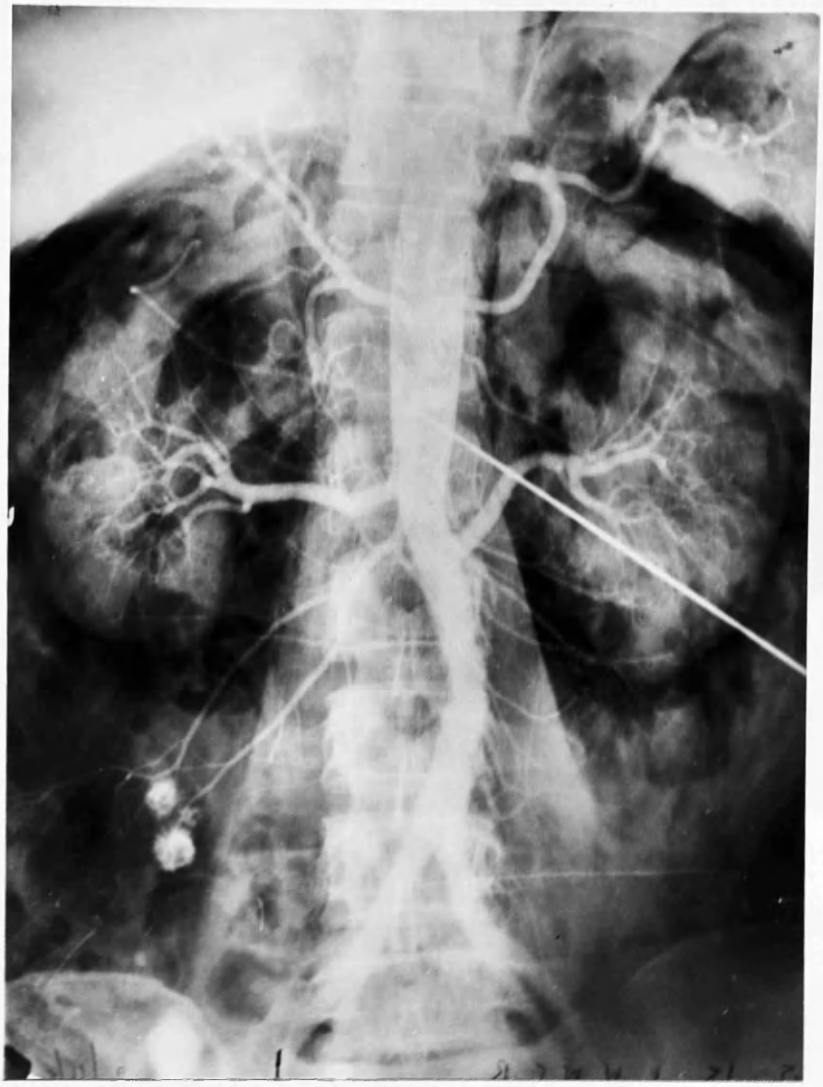

Fig. 192 Case 120.

Adrenal Cortical Hyperplasia.

Arteriogram shows no definition of adrenal arteries. Early nephrogram phase suggests possibility of enlarged left adrenal gland.

Fig. 193 Case 121.

Vesical Neoplasm.

Arteriogram shows no significant difference in blood supply to the bladder.

Fig. 194 Case 123.

Vesical Neoplasm.

Arteriogram shows increased vascularity of the left side affecting mainly the inferior vesical and internal pudendal arteries.

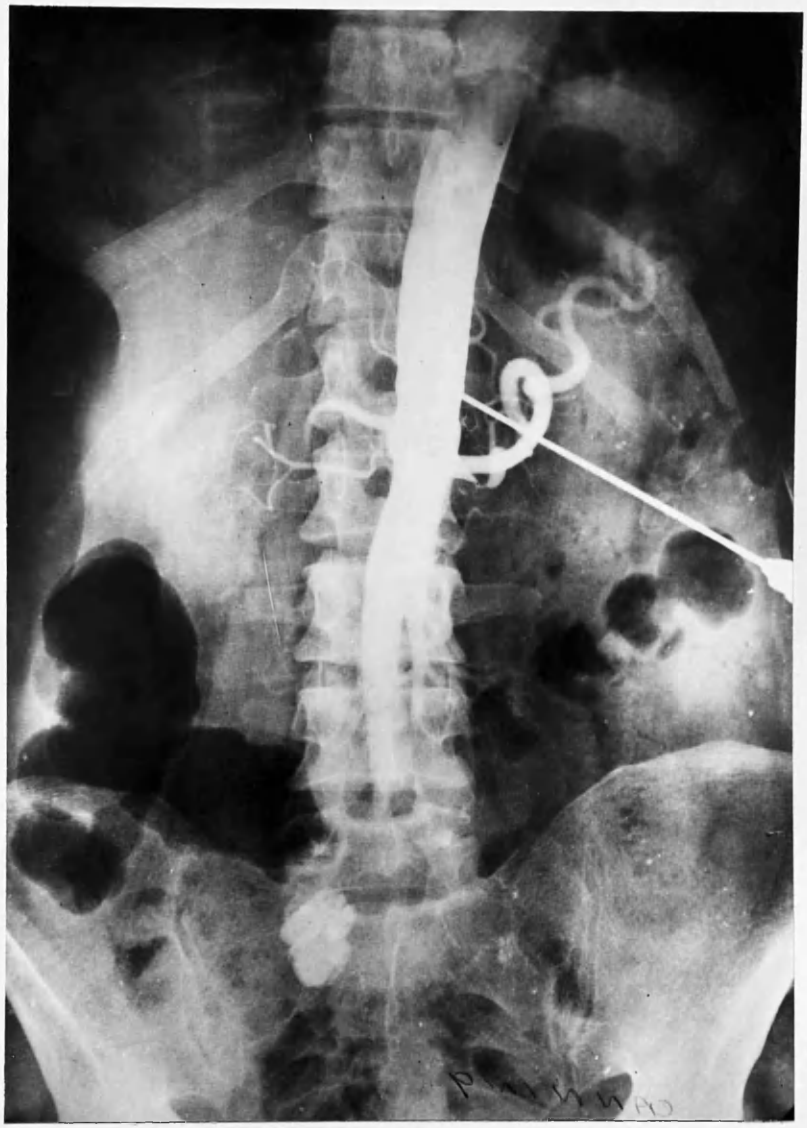

Fig. 195 Case 124.

Hypertension.

Arteriogram shows gross vascular deficiency of each kidney. The right renal artery is small and narrow and the left artery shows athero-sclerotic stenosis near its origin.

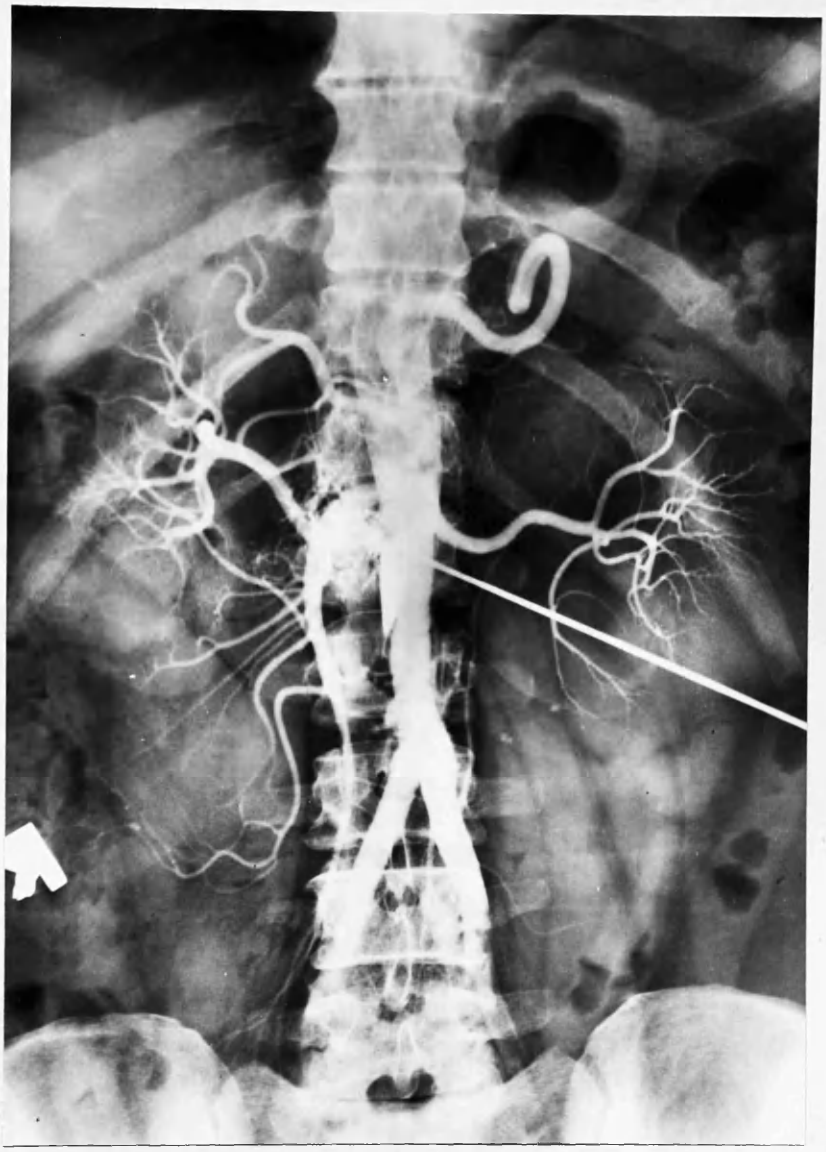

Fig. 196 Case 125.

Hypertension.

Arteriogram shows some thinning of the left renal branches but no significant intrinsic vascular change.

Fig. 197 Case 127.

Hypertension.

Excretion urogram shows slight pelvic dilatation and clubbing of the calyces of the right kidney. There is marked kinking of the ureter.

Fig. 198 Case 127.

Hypertension.

Arteriogram shows irregular athero-sclerosis of aorta. Reduction in vascularity of each kidney.

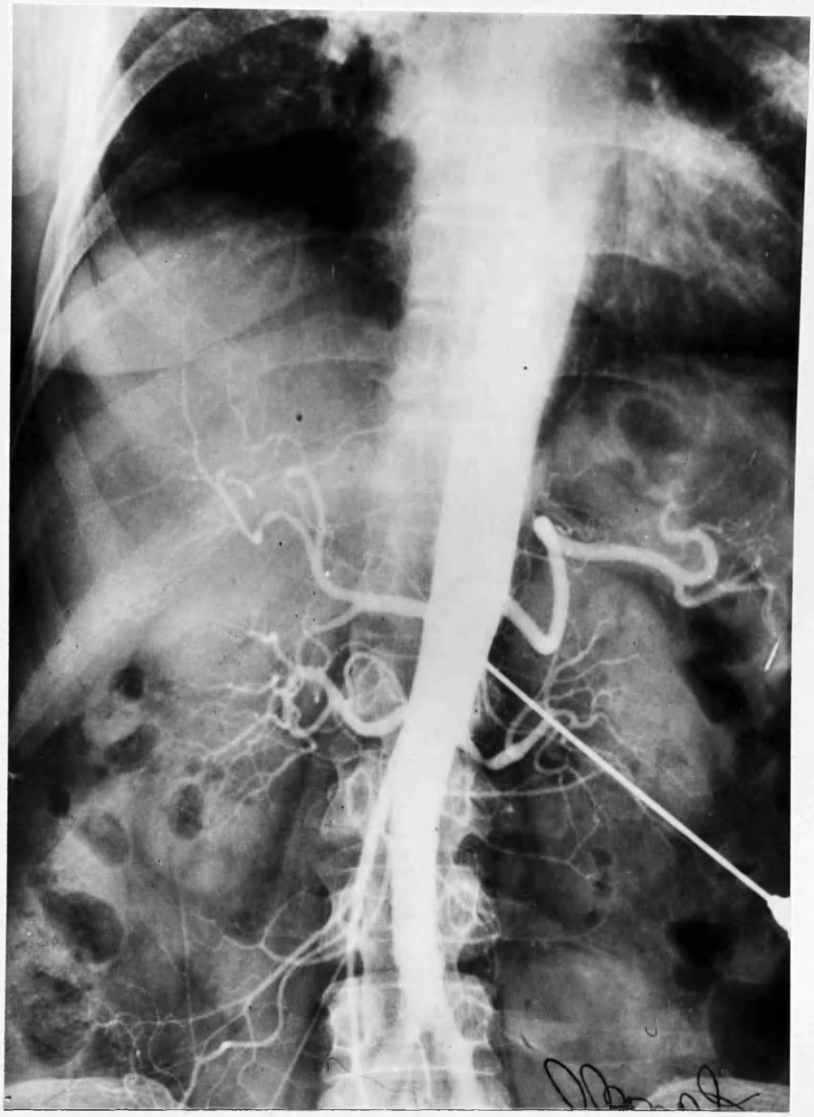

Fig. 199 Case 128.

Hypertension.

Arteriogram shows stenosis of main left renal artery near its origin. Total renal vascularity satisfactory.

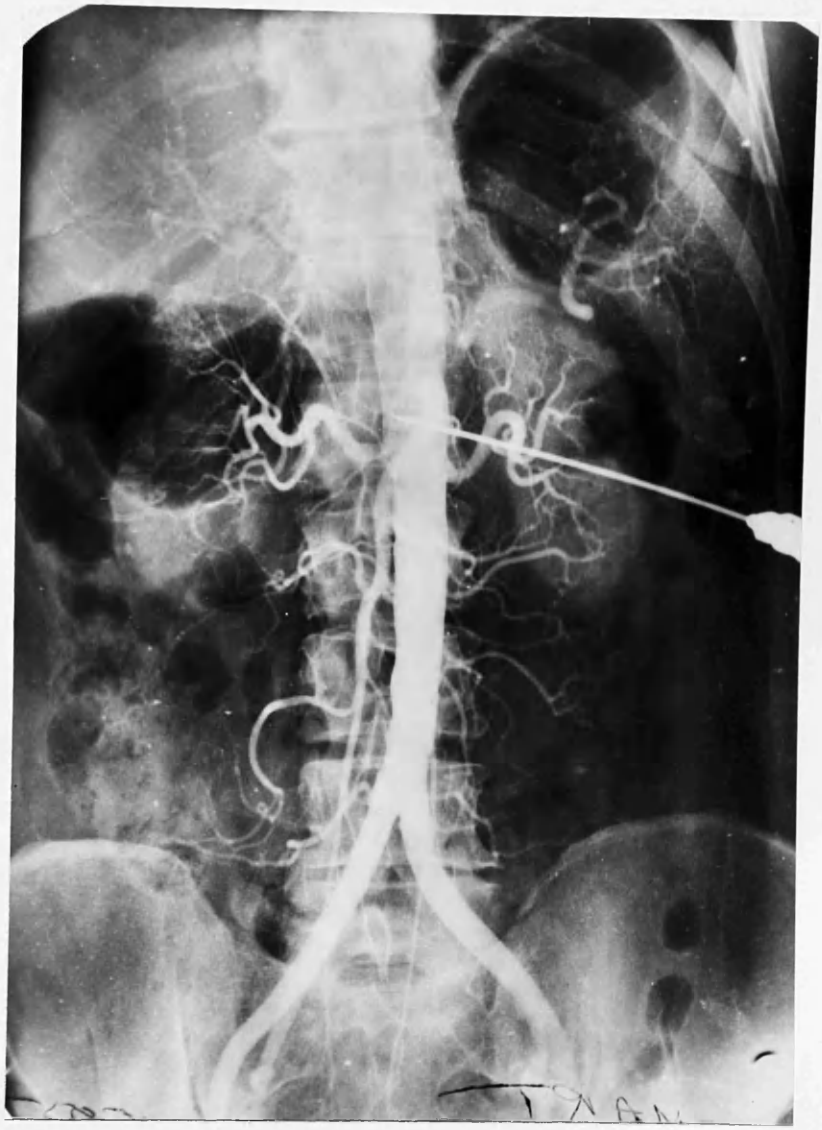

Fig. 200 Case 129.

Hypertension.

Arteriogram shows slight narrowing of left renal artery but good parenchymal vascularity.

Fig. 201 Case 130.

Hypertension.

Arteriogram shows athero-sclerosis affecting the aorta and also involving the origin of the right main renal artery.

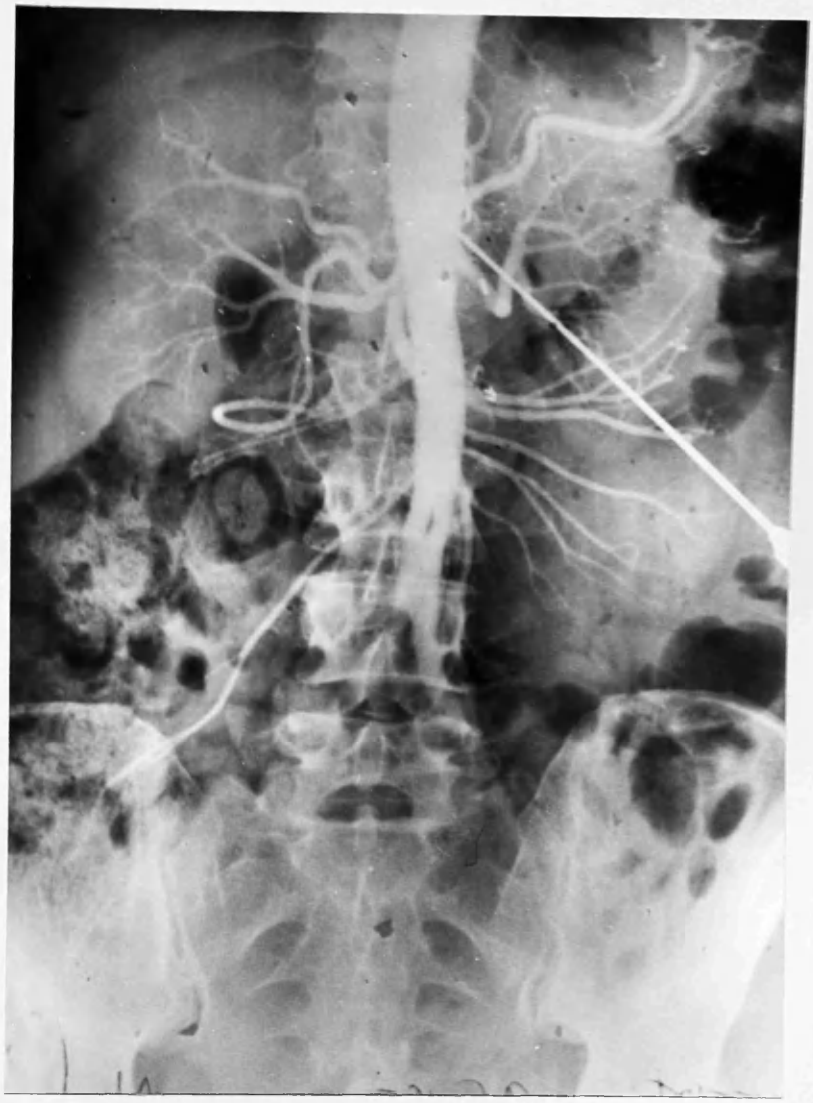

Fig. 202 Case 131.

Hypertension.

Arteriogram shows athero-sclerosis of aorta which has a high bifurcation. Renal vascularity satisfactory. Note silver clips inserted at splanchnicectomy.

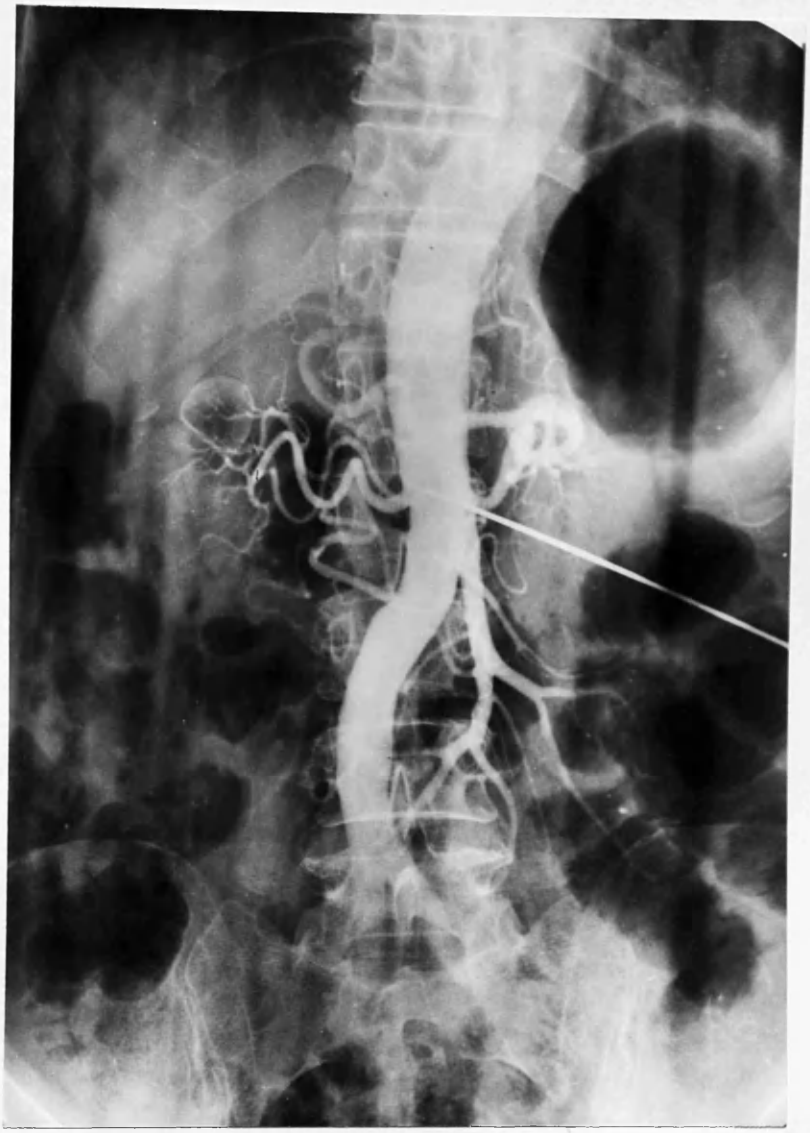

Fig. 203 Case 132.

Hypertension.

Arteriogram shows irregular, displaced, athero-sclerotic aorta. Left renal artery shows slight narrowing at its origin.

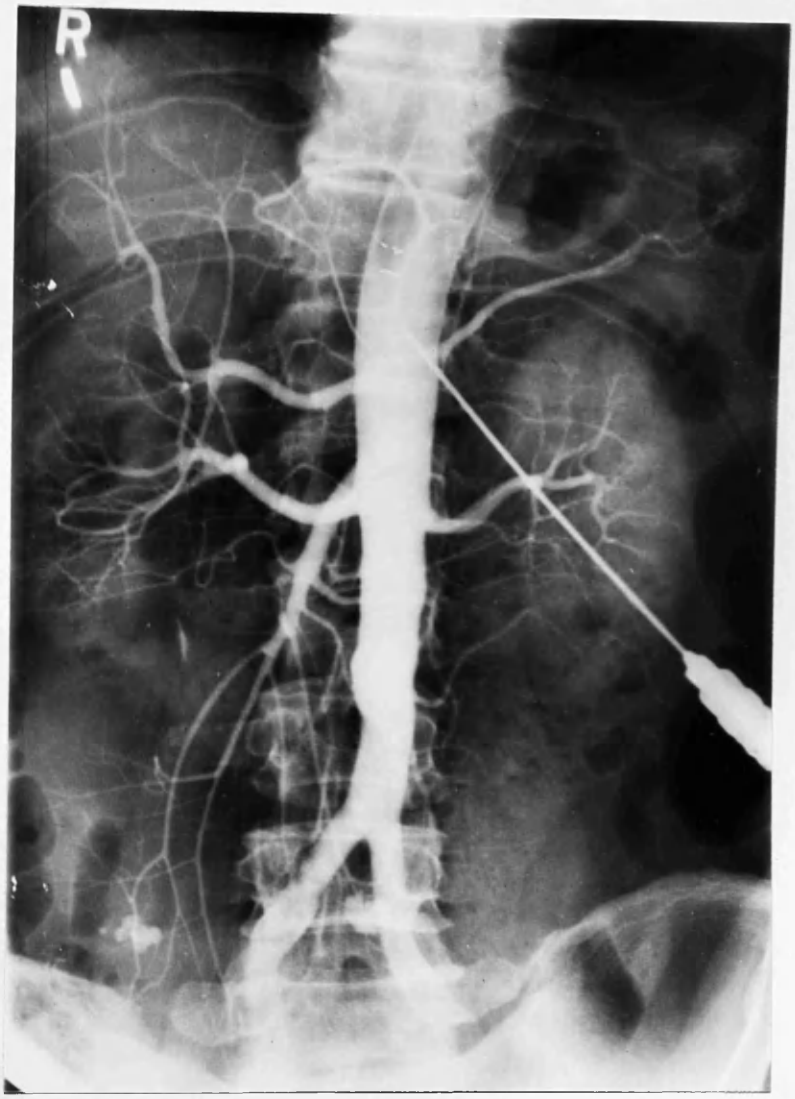

Fig. 204 Case 135.

Hypertension.

Arteriogram shows normal renal vascularity with no separate supply to smaller upper segment of duplicated left kidney.

Fig. 205 Case 136.

Hypertension.

Arteriogram shows abrupt ending to interlobar vessels of left kidney with no appreciable cortical branching.

Fig. 206 Case 137.

Hypertension.

Ascending pyelogram shows dilatation of right renal pelvis with small flattened calyces.

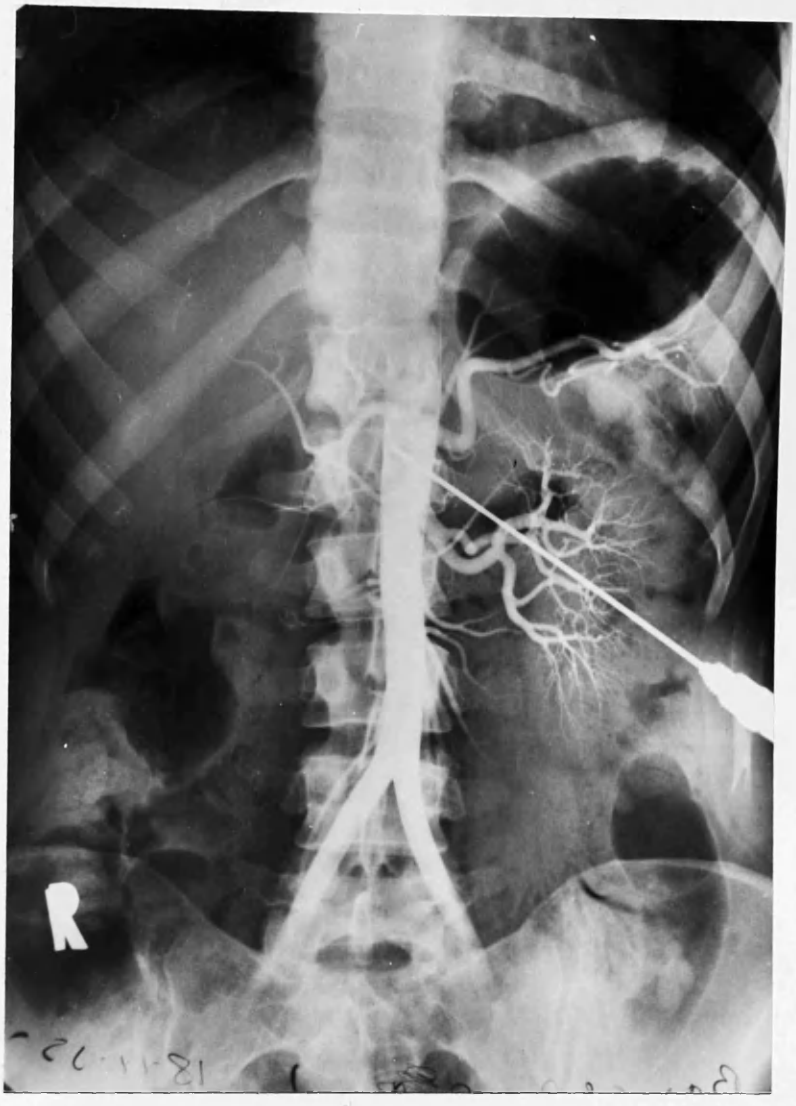

Fig. 207 Case 137.

Hypertension.

Arteriogram shows atrophic right renal artery with two small divisions and no cortical supply.

Fig. 208 Case 138.

Hypertension.

Arteriogram shows block in the right renal artery just beyond its origin.

Fig. 209 Case 140.

Aortic Aneurysm.

First film shows dye held up before entering sac.

Fig. 210 Case 140.

Aortic Aneurysm.

Second film shows dye entering sac.

Fig. 211 Case 140.

Aortic Aneurysm.

Third film shows sac outlined with dye which is now entering common iliac arteries.

Fig. 212 Case 140.

Aortic Aneurysm.

Film taken after lateral puncture shows anterior displacement of aorta above dilated sac. Note the relation of aortic branches, especially splenic and renal arteries.

Fig. 213 Case 142.

Aortic Aneurysm.

First film shows irregularity of aorta and deviation to the left where dye is entering sac.

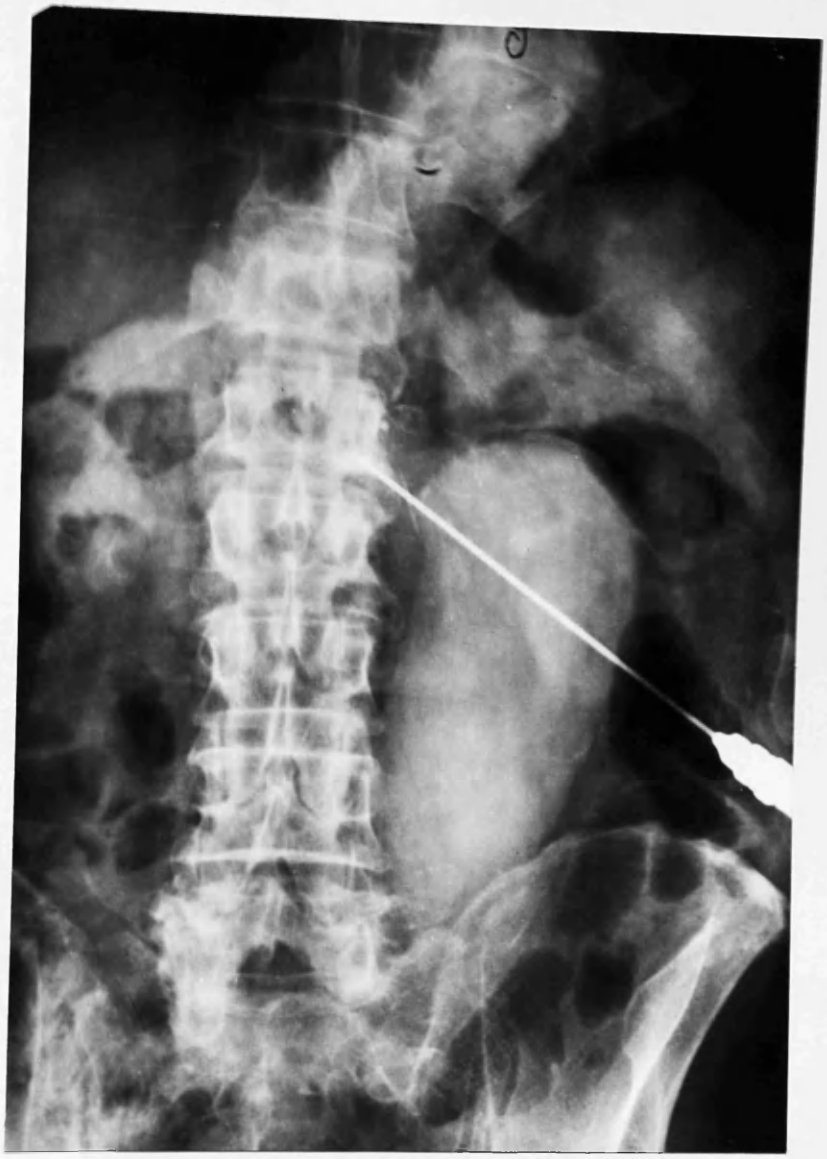

Fig. 214 Case 142.

Aortic Aneurysm.

Second film shows sac filled with dye.

Fig. 215 Case 143.

Aortic Block.

Arteriogram shows calcification near aortic bifurcation. The major vessel entering the pelvis is the superior haemorrhoidal artery.

Fig. 216 Case 145.

Common Iliac Artery Block.

Arteriogram shows occlusion of left common iliac artery. There is atheromatous stenosis of the right common iliac vessel.

Fig. 217 Case 146.

Common Iliac Artery Block.

Arteriogram shows occlusion of right common iliac artery. The left common iliac vessel shows some stenosis but with good distal filling.

Fig. 218 Case 147.

Common Iliac Artery Block.

Arteriogram shows occlusion of left common iliac artery. Athero-sclerotic irregularity affects the right common and internal iliac arteries.

Fig. 219 Case 147.

Common Iliac Artery Block.

Later arteriogram shows retrograde filling from superior gluteal and internal pudendal arteries.

Fig. 220 Case 148.

Arterio-sclerosis - Iliac Arteries.

Arteriogram shows irregularity of all iliac arteries but no gross dilatation.

Fig. 221 Case 149.

Common Iliac Artery Stenosis.

Arteriogram shows marked stenosis of right common iliac and occlusion of right external iliac artery.

Fig. 222 Case 149.

Common Iliac Artery Block.

Arteriogram shows occlusion of right common iliac artery.

Fig. 223 Case 151.

Athero-sclerosis Common Iliac Arteries.

Arteriogram shows irregularity of common and external iliac arteries. Occlusion of both internal iliac arteries.

Fig. 224 Case 152.

External Iliac Artery Block.

Arteriogram shows stenosis of right external iliac origin with distal occlusion.

Fig. 225 Case 152.

External Iliac Artery Block.

Later film shows anastomosis via internal pudendal and obturator arteries.

Fig. 226 Case 153.

External Iliac Artery Block.

Arteriogram shows gross arterio-sclerosis with stenosis of right common iliac and left external iliac vessels. Occlusion of right external iliac artery.

Fig. 227 Case 154.

Femoral Artery Aneurysm.

Arteriogram shows ovoid sac overlying the left femoral head.

Fig. 228 Case 155.

Femoral Artery Stenosis.

Arteriogram shows calcification of left superficial femoral artery which is stenosed and dye has not entered.

Fig. 229 Case 155.

Femoral Artery Stenosis.

Arteriogram (after compression of right femoral) shows trickle of dye through narrow left superficial femoral artery.

Fig. 230 Case 156.

Femoral Artery Repair.

Arteriogram (after disobliterative operation on right femoral artery) shows patent vessel with only slight stenosis.

Fig. 231 Case 157.

Femoral Artery Block.

Arteriogram shows occlusion of right superficial femoral artery at mid-thigh level.

Fig. 232 Case 158.

Femoral Artery Block.

Arteriogram shows irregularity of iliac arteries with constriction at origin of right common femoral artery.

Fig. 233 Case 159.

Sarcoma of Ilium.

Arteriogram shows considerable vascularity in area of bone tumour below right iliac crest. Note hypertrophy of gluteal arteries on that side.

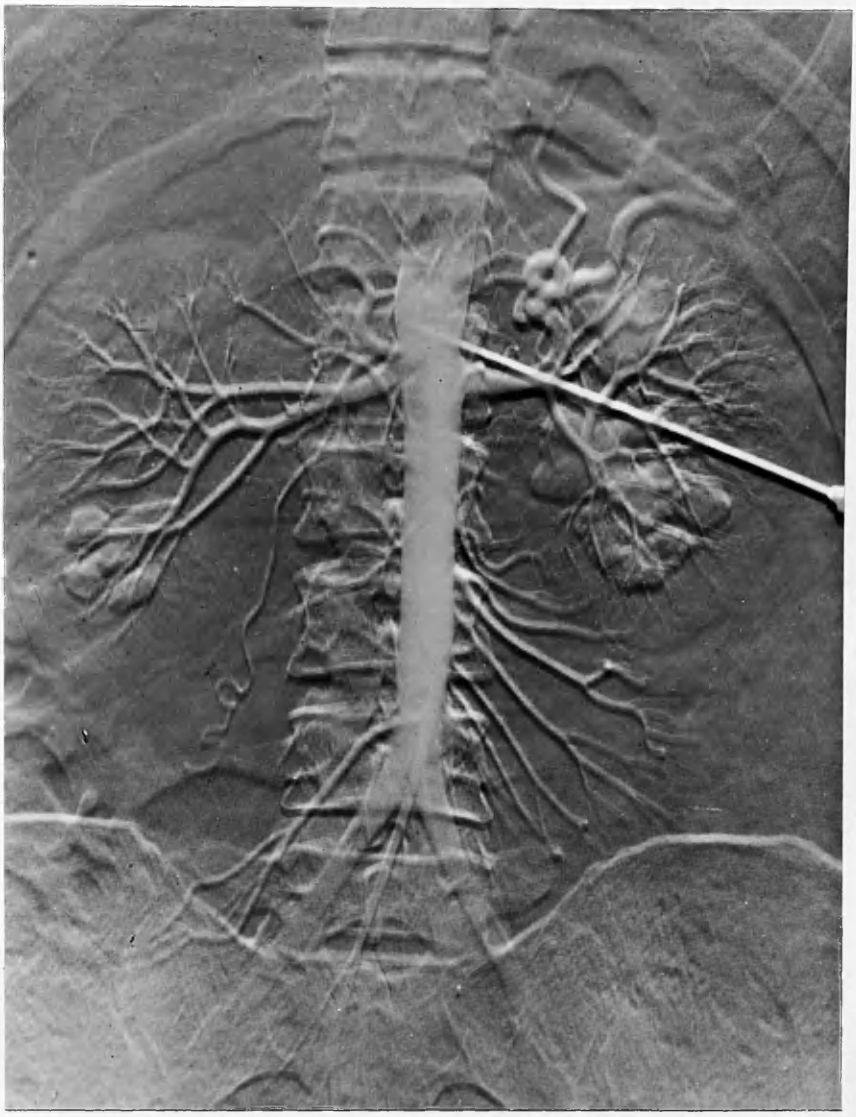

Fig. 234 Case 86.

Three-dimensional Photograph.

This effect gives a truer appreciation of the relation of the various renal arterial branches. Compare with flat photograph (Fig. 143) of the same patient.

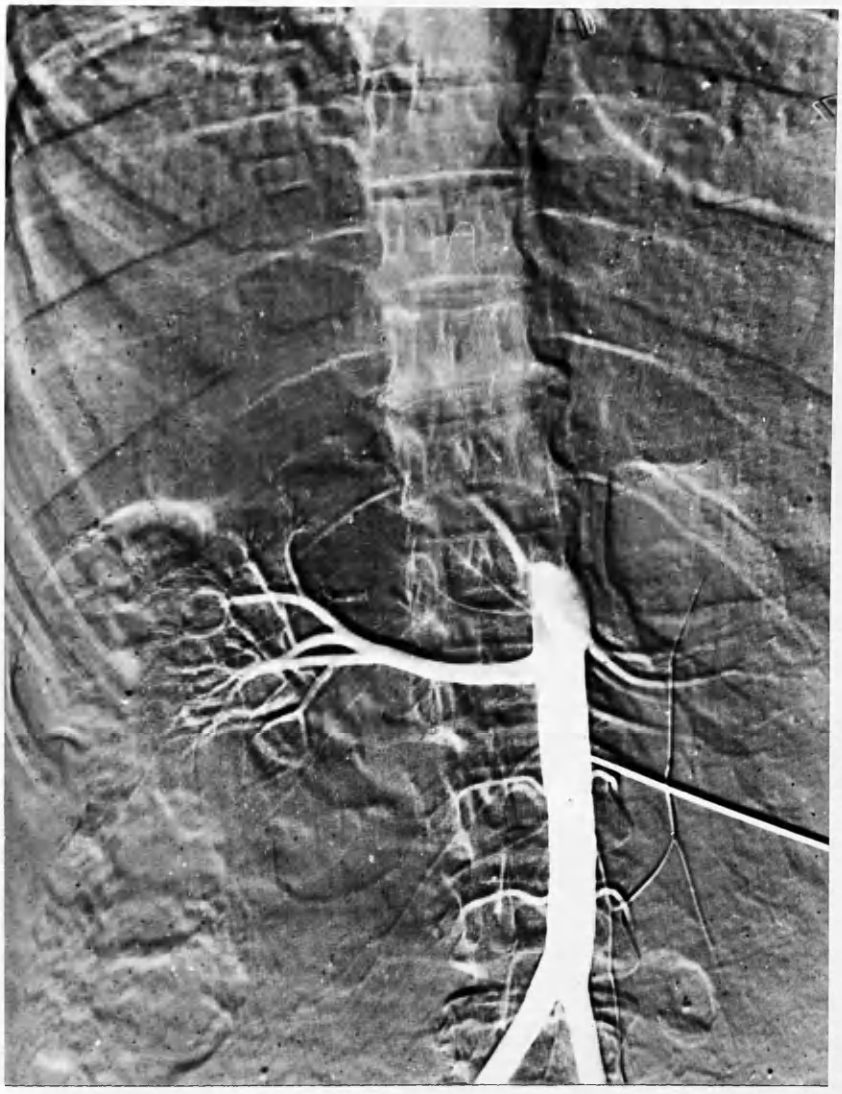

Fig. 235 Case 73.

Three-dimensional Photograph.

Note relation of renal branches and course of lumbar arteries. Compare with Fig. 124.

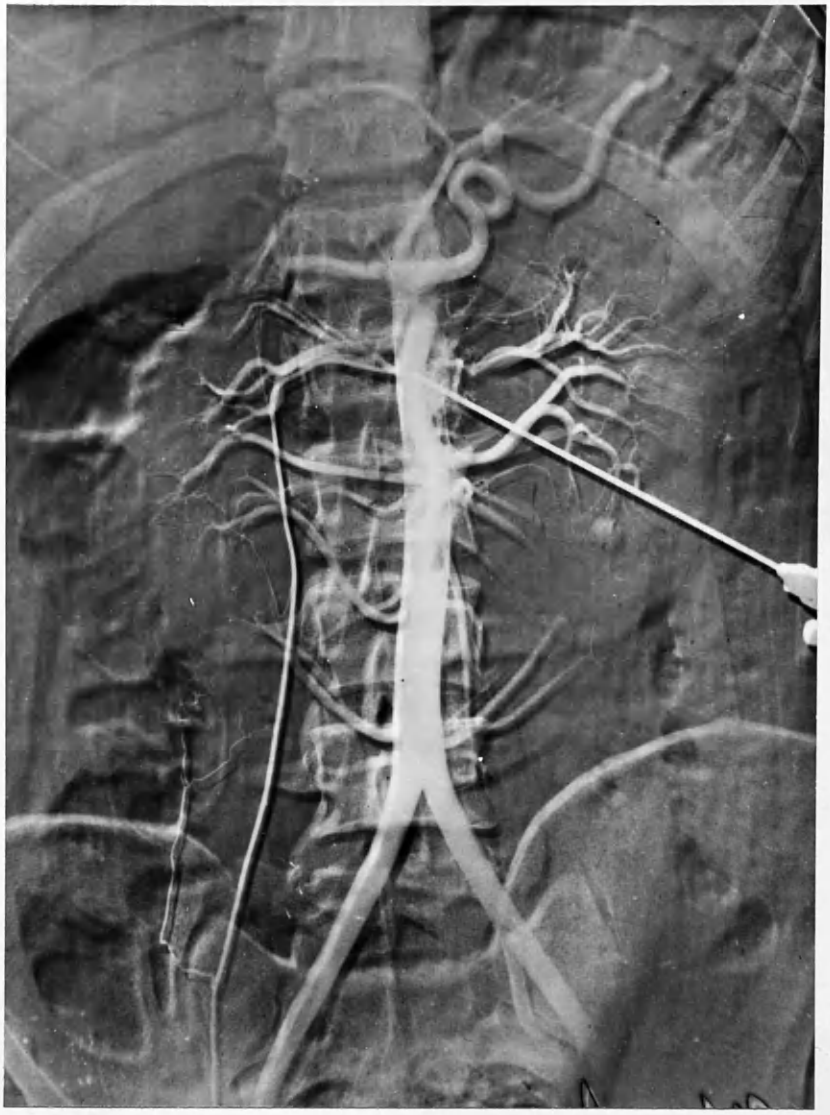

Fig. 236 Case 10.

Three-dimensional Photograph.

Note relation of the numerous renal arteries to the lumbar and right testicular arteries. Compare with Fig. 24.